N
39
33
. 24
. 1
NGS

# MEMOIRS OF THE GEOLOGICAL SURVEY, SCOTLAND.

GEOLOGICAL SURVEY OF GREAT BRITAIN

## SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN.

ENGI STORAGE

## VOL. XXIV.—CANNEL COALS, LIGNITE AND MINERAL OIL IN SCOTLAND.

BY

W. GIBSON, D.Sc.;

FROM CONTRIBUTIONS BY

J. S. Flett, F.R.S., E. M. Anderson, M.A., G. W. Lee, D.Sc.; and M. Macgregor, M.A.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

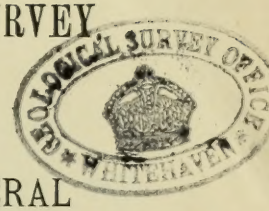
LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.

And to be purchased from
E. STANFORD, Ltd., 12, 13, and 14, Long Acre, London, W.C.2;
W. & A. K. JOHNSTON, Ltd., 2, St. Andrew Square, Edinburgh;
HODGES, FIGGIS & Co., Ltd., 20, Nassau Street, and
17 & 18, Frederick Street, Dublin;
or from any Agent for the sale of Ordnance Survey Maps;
or through any Bookseller; from the DIRECTOR GENERAL
Ordnance Survey, Southampton.

1922.

*Price 2s. Net.*

# MEMOIRS OF THE GEOLOGICAL SURVEY SCOTLAND.



## SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN.

## VOL. XXIV.—CANNEL COALS, LIGNITE AND MINERAL OIL IN SCOTLAND.

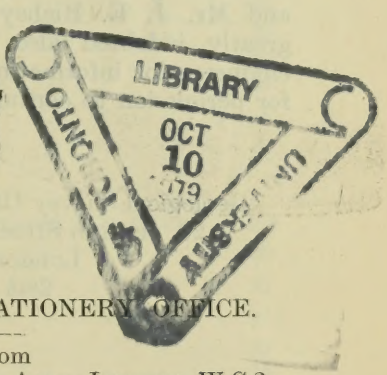
BY

W. GIBSON, D.Sc.;

FROM CONTRIBUTIONS BY

J. S. Flett, F.R.S., E. M. Anderson, M.A., G. W. Lee, D.Sc.; and M. Macgregor, M.A.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.




LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.

And to be purchased from
E. STANFORD, Ltd., 12, 13, and 14, Long Acre, London, W.C.2;
W. & A. K. JOHNSTON, Ltd., 2, St. Andrew Square, Edinburgh;
HODGES, FIGGIS & Co., Ltd., 20, Nassau Street, and
17 & 18, Frederick Street, Dublin;
or from any Agent for the sale of Ordnance Survey Maps;
or through any Bookseller; from the DIRECTOR GENERAL,
Ordnance Survey, Southampton.

1922.

*Price 2s. Net.*

## PREFACE.

Owing to changes in the process of manufacture of coal gas, mining for cannel coal has declined in Scotland of recent years. During the war, however, much enquiry was made regarding the possibility of using cannel as a source of fuel oil, and part of the information collected by the staff of H.M. Geological Survey at that time has been incorporated in this Memoir. Enquiries were received also regarding Scottish lignites and oil shales outside of the recognised oil-shale fields. With a few exceptions, all the deposits described in this Memoir are at present regarded as not worth working on a large scale.

This volume may be regarded as a second part of Volume VII of the Special Reports on the Mineral Resources of Great Britain, 'Mineral Oil, Kimmeridge Oil Shale, Lignite, Jet, Cannel Coals, Natural Gas :—England and Wales'; and as such it was intended originally to be issued.

Dr. Gibson has acted as editor of this Memoir and has determined its general form. Mr. E. M. Anderson describes the cannels of Ayrshire, Dr. Lee those of Fife, and Dr. Gibson those of Midlothian. Dr. Flett compiled the chapter on lignite and Secondary coals, partly from information supplied by Dr. Lee, Mr. Anderson and Mr. G. V. Wilson. Mr. Macgregor has furnished particulars of the cannels of the Central Coalfield, and Mr. J. E. Richey gave assistance in Ayrshire. We are greatly indebted also to many mine managers and mining engineers for information regarding coal and shale deposits, and for permission to consult their mining plans and bore records.

JOHN S. FLETT,
Director.

Geological Survey Office,
28, Jermyn Street,
London, S.W.1.
28*th March*, 1922.

# CONTENTS.


PAGE

PREFACE - - - - - - - - - - - - - ii

## CHAPTER I.

CANNEL COALS - - - - - - - - - - - 1

*Introduction* - - - - - - - - - - - 1

1. *Midlothian Coalfield by* W. GIBSON - - - - - 3
   Lower Limestone Group - - - - - - 6
   Limestone Coal Group - - - - - - - 7
   Upper Limestone Group - - - - - - - 9
   Lower Coal Measures - - - - - - - 10

2. *Central Coalfield by* M. MACGREGOR - - - - - 10
   Lower Limestone Group - - - - - - - 11
   Limestone Coal Group - - - - - - - 12
   Upper Limestone Group - - - - - - - 13
   Productive Coal Measures - - - - - - - 14

3. *Douglas Coalfield by* M. MACGREGOR - - - - - 17
   Limestone Coal Group - - - - - - - 17
   Upper Limestone Group - - - - - - - 17
   Lower Coal Measures - - - - - - - 17

4. *Fifeshire Coalfield by* G. W. LEE - - - - - - 18
   Calciferous Sandstone Series - - - - - - 18
   Lower Limestone Group - - - - - - - 18
   Limestone Coal Group - - - - - - - 20
   Upper Limestone Group - - - - - - - 22
   Lower or Productive Coal Measures - - - - - 23

5. *Ayrshire Coalfield by* E. M. ANDERSON - - - - - 25
   Limestone Coal Group - - - - - - - 25
   Upper Limestone Group - - - - - - - 27
   Lower or Productive Coal Measures - - - - - 27

6. *Argyllshire Coalfield* - - - - - - - - - 30

## CHAPTER II.

SECONDARY AND TERTIARY COALS AND LIGNITES *by* J. S. FLETT - 30

*Introduction* - - - - - - - - - - - 30

*Lower Lias* - - - - - - - - - - - 31

*Upper Lias* - - - - - - - - - - - 31

*Great Oolite* - - - - - - - - - - - 32
   Brora - - - - - - - - - - - 32
   Shandwick - - - - - - - - - - - 36
   Skye - - - - - - - - - - - - 36

*Middle Oolite* - - - - - - - - - - - 37

*Upper Oolite* - - - - - - - - - - - 37

*Tertiary* - - - - - - - - - - - - 37
   Mull - - - - - - - - - - - - 37
   Skye - - - - - - - - - - - - 41
   Canna - - - - - - - - - - - - 43


z (78)17455 Wt 34128—S 28/1468 750 12/22 E & S A 2

## CHAPTER III.

PAGE

OIL SHALES (MINOR OCCURRENCES) *by* J. S. FLETT - - - 43

*Introduction* - - - - - - - - - - - - 43

*Oil Shales in the Carboniferous Rocks* - - - - - 46
Midlothian - - - - - - - - - - - 46
Margins of the Central Coalfield - - - - - 49
Berwickshire and Haddingtonshire - - - - - 51

*Oil Shales in the Jurassic Rocks* - - - - - - - 52
Raasay and Skye - - - - - - - - - 52

## CHAPTER IV.

MINERAL OIL *by* W. GIBSON - - - - - - - - - 56

*Natural Occurrences* - - - - - - - - - - 56

St. Flanans - - - - - - - - - - 56
Broxburn - - - - - - - - - - 57
St. Catherine's Well - - - - - - - - - 58

*Recent Explorations for Oil* - - - - - - - - 58

Introduction - - - - - - - - - - 58
West Calder Boring - - - - - - - - - 59
D'Arcy Boring - - - - - - - - - - 60

INDEX - - - - - - - - - - - - - 64

---

## ILLUSTRATIONS.

FIG. PAGE

1.—Comparative Vertical Sections of the Limestone Coal and Lower Limestone Groups in the Midlothian and Haddington Coalfield - - - - - - - - - - - - - 4
(Fig. 14, p. 167. Special Reports on the Mineral Resources of Great Britain. Vol. XI. 'Iron Ores of Scotland,' *Mem. Geol. Surv.*)

2.—General Succession of the Coals and Ironstones in the Limestone Coal Group of Western and Central Fife - - - - - 19
(Fig. 12, p. 137. Special Reports on the Mineral Resources of Great Britain. Vol. XI. 'Iron Ores of Scotland,' *Mem. Geol. Surv.*)

3.—General Vertical Section of the Carboniferous Strata of Mid and West Lothian - - - - - - - - - - 47
(After Fig. 1, p. 5. 'The Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 1912 2nd Ed.)

4.—Geological Map of the Island of Raasay - - - - - - 53
(Fig. 16, p. 199. Special Reports on the Mineral Resources of Great Britain. Vol. XI. 'Iron Ores of Scotland,' *Mem. Geol. Surv.*)

5.—Diagrammatic Section Illustrating the Sequence of the Jurassic Rocks below Dun Caan, Isle of Raasay - - - - - 54
(Fig. 2, p. 41. 'Summary of Progress for 1913,' *Mem. Geol. Surv.*)

6.—Diagrammatic Section Illustrating the Sequence of the Jurassic Rocks in the Cliff between Holm and Prince Charles's Cave, Isle of Skye - - - - - - - - - - - 55
(Fig. 3, p. 41. 'Summary of Progress for 1913,' *Mem. Geol. Surv.*)

---

## CHAPTER I.

### CANNEL COALS.

A typical cannel burns readily with a long smoky flame like a candle, from which the name cannel is said to originate. In burning, it produces a crackling noise, whence the term 'parrot,' the general designation for this variety of coal in Scotland. It frequently passes laterally into coal, the intermediate stages being known as 'parroty coal.' With the intercalation of shale and ironstone, as is not infrequent, the bed is termed 'wild parrot,' 'irony parrot,' 'parroty shale.'

A typical cannel differs from ordinary coal in being massive, having a satiny lustre, with a marked conchoidal fracture, and not soiling the hand. Jointing is regular and usually pronounced. It weathers slowly and can be used for light foundations. It does not cake in burning and gives a pulverulent coke.

Lenticles and ribs of cannel commonly accompany seams of coal. When cannel occurs as a separate bed, it seldom extends over an area of more than a few square miles. Thus cannels do not form a reliable source of raw material. A rib of cannel may occur at any part of a coal, and not infrequently changes its position from the bottom to the middle or upper part of a coal in contiguous areas. When at the top or bottom of a high-class coal it is often left to form the roof or floor.

Scotch cannels rarely exceed 2 ft. in thickness, though parroty shales may run up to 3 or 4 ft. The purer kinds are *commonly* from 6 in. to 10 in. thick and even then are not general, but lenticles of an inch or less are by no means rare, and are sent out with the coal. The cannel parts of the Great Seam and the Parrot Coal in the Limestone Coal Group (Edge Coal Group) are two well-known Scotch cannels and still mined. Many other cannels occur, but are more often regarded as waste than as a valuable constituent of the seam of coal, or occur in such limited quantities as to be negligible.

Cannel coals contain from 25 to 45 per cent. fixed carbon and from 45 to 70 per cent. volatile matter, in contrast with from 45 to 75 per cent. fixed carbon and from 20 to 45 per cent. volatile matter for an ordinary bituminous coal. The ash content is always high, ranging from 2·70 per cent. to as much as 60 per cent. in the case of parroty shale.

It is generally accepted that cannels were formed in water. A microscopic study shows that they include algæ, spores, and drifted vegetable matter. The idea that they consist largely of

algæ is disputed. The close relation of cannel to shale is seen in the high ash content of many cannels, due to the washing in of mud during the formation of the bed.

Cannel coal is chiefly used for the enrichment of coal gas, since the better grade cannels yield from 50 to 60 per cent. volatile matter as compared to 30 or 40 per cent. for many of the so-called 'gas coals.' The gas from cannel also has double the illuminating power of that from gas coals. The introduction of the incandescent gas mantle has, however, resulted in a less use of cannel for gas enrichment.

The coke produced from cannel is, as a rule, pulverulent, soft, and crumbles at once into a powder.

Recently attention has been paid to cannels and allied substances as a source of oil and other chemical by-products.

During the later stages of the Great War, experiments on cannels as a source of oil were carried out under the Ministry of Munitions at the Dundee Gasworks. For these experiments the cannel was supplied by :—

| | | Tons. | Cwt. |
|---|---|---|---|
| Lochgelly Iron & Coal Co., Ltd. | Lochgelly Cannel | 1,535 | 1 |
| Archibald Russell, Ltd. | Tannochside | 1,182 | 0 |
| Lothian Coal Co., Ltd. | Newbattle | 5,689 | 12 |
| Carron Company | Cadder | 823 | 19 |
| Wm. Baird & Co., Ltd. | Muirkirk | 279 | 12 |
| Wishaw Coal Co., Ltd. | Dalzell | 391 | 18 |
| A. & G. Anderson | Blairmuckhill | 80 | 13 |
| Wm. Dixon, Ltd. | Wilsontown | 71 | 10 |
| Fife Coal Co., Ltd. | Lumphinnans | 337 | 7 |
| ,, ,, | Dunniker | 656 | 19 |
| Woodhall Coal Co., Ltd. | Pencaitland | 1,268 | 12 |
| The Arden Coal Co., Ltd. | Bankend | 164 | 6 |
| The United Collieries, Ltd. | Clydeside | 391 | 9 |
| ,, ,, | Kirkwood | 14 | 6 |
| Wm. Barr & Sons, Ltd. | Bellfield | 420 | 19 |
| ,, ,, | Allanton | 61 | 2 |
| The Glasgow Iron & Steel Co., Ltd. | Shieldsmain | 93 | 10 |
| The Shotts Iron & Steel Co., Ltd. | Loanhead | 141 | 9 |
| The New Cumnock Collieries, Ltd. | Knockshinnoch Cannel | 308 | 8 |
| ,, ,, | Bank Cannel | 60 | 18 |
| The Garallan Coal Co., Ltd. | Garallan | 101 | 1 |
| The Caprington & Auchlochan Coll., Ltd. | Auchlochan | 778 | 14 |
| ,, ,, | Muirburn | 995 | 1 |
| Waddell & Son, per Slight & McKimmie | Dalquhandy | 501 | 10 |
| Summerlee Iron Co., Ltd., per A. G Anderson. | Blackhill | 501 | 6 |
| Wilsons & Clyde Coal Co., Ltd. | Clyde | 113 | 2 |
| ,, ,, | Douglas Castle | 26 | 3 |
| Hirst Coal Co., Ltd., per Slight & McKimmie. | South Blair | 198 | 3 |
| A. G. Moore, per Slight & McKimmie | Dalkeith Cannel | 771 | 19 |
| Coltness Iron Co., Ltd. | Douglas | 16 | 3 |
| Per Jas. & Wm. Brown | Giffnock | 16 | 18 |
| | | 17,993 | 10 |

The results obtained between 4th October 1918 and 25th January 1919 by the carbonisation of 15,387·35 tons were :—

| | |
|---|---|
| Gas made, cubic feet | 236,728,900 |
| Cannel oil made, gallons | 352,615 |
| Coke and breeze, tons | 8,778·45 |

The output of cannel coal has been recorded separately from other forms of coal in only a few cases, but an interesting account is given in the ' Mineral Statistics ' for 1865 (*Mem. Geol. Surv.*), p. 219.

It is there stated that ' at a meeting of coalowners, recently held in Glasgow, the estimated quantity raised in 1865 was given as follows :—

| | Tons. |
|---|---|
| Lanarkshire | 172,000 |
| Linlithgowshire | 28,000 |
| East and Mid-Lothian | 55,000 |
| Fifeshire | 29,000 |
| Ayrshire | 38,000 |
| | 322,000 |

The stock of cannel coal on hand was then stated to be 61,500 tons, making the total quantity raised as 383,500 tons. Mr. Binney informs us that nearly 100,000 tons of this is used in making oil.'

The oil-producing capacity of some of the coals then used is given as :—

| | | | |
|---|---|---|---|
| Boghead | produces | 128 | gallons per ton. |
| Methil [Pirnie Parrot ?] | ,, | 90 | ,, |
| Capeldræ [Parrot ?] | ,, | 81 | ,, |
| Lesmahagow [Gas Coal] | ,, | 78 | ,, |
| Rochsoles [Musselband above Kiltongue ?] | ,, | 72 | ,, |

Owing to the extremely lenticular occurrence of cannel it is impossible to give in figures actual reserves. In the following account the statement that in particular areas the reserves are large, means that an output amounting to several hundred tons per week could be obtained for a considerable time, in contra-distinction to an area where the supply is known to be inconstant or of no account.

## 1. MIDLOTHIAN COALFIELD.

The coalfield consists of a well defined basin-fold trending nearly north and south. The Carboniferous sequence is very complete and is divisible into the following groups :—

| | |
|---|---|
| Coal Measures | Middle (Westphalian) Coal Measures.<br>Lower (Lanarkian) Coal Measures. |
| Millstone Grit | Upper Roslin Sandstone.<br>Lower Roslin Sandstone. |
| Carboniferous Limestone Series | Upper Limestone Group.<br>Limestone Coal (Edge Coal) Group.<br>Lower Limestone Group. |
| Calciferous Sandstone Series | Oil Shale Group.<br>Cement Stone Group. |

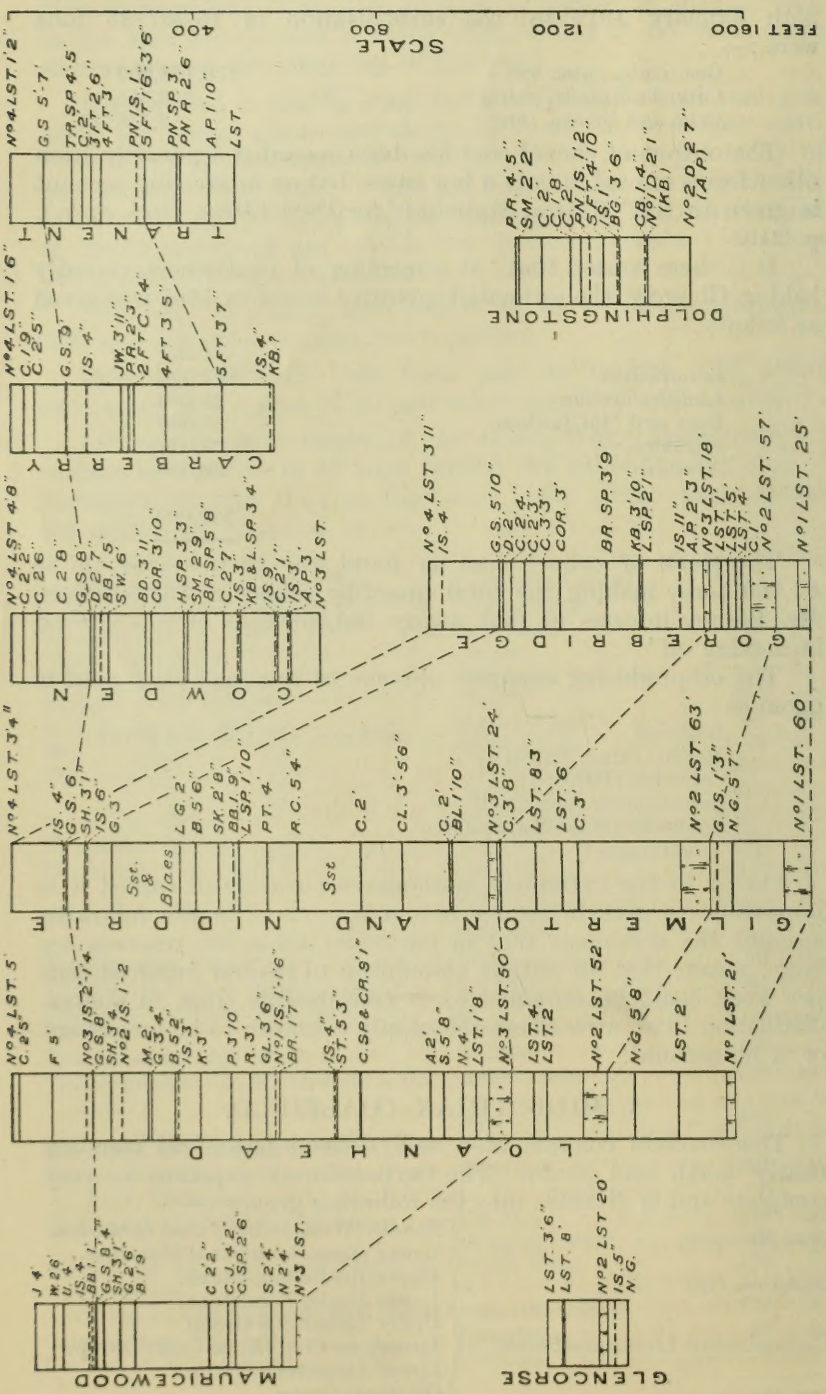



FIG. 1.—Comparative Vertical Sections of the Limestone Coal and Lower Limestone Groups in the Midlothian and Haddington Coalfield.

## List of Abbreviations used in Fig. 1.

A. Andrews Coal.
A.P. Arniston Parrot Coal.
B. Blackchapel Coal.
BD. Blackbird Coal.
BG. Beggar Coal.
BL. Blue Coal.
BR. Browns Coal.
BR.SP. Bryans Splint Coal.
C. Coal.
2 ft. C. Two-foot Cherry Coal.
3 ft. Three-foot Coal.
4 ft. Four-foot Coal.
5 ft. Five-foot Coal.
C.J. Corbie Jewel Coal.
CL. Carleton Coal.
COR. Coronation Coal.
C.SP. Corbie Splint Coal.
C.SP & CR. Corbie Splint & Craig Coals.
D. Diamond Coal.
No. 1 D. No. 1 Diamond Coal.
No. 2 D. No. 2 Diamond Coal
F. Flex Coal.
G. Gillespie Coal.
GL. Glass Coal.
G.S. Great Seam Coal.
H.SP. Hard Splint Coal.
IS. Ironstone.
No. 1. IS. Loanhead No. 1 Ironstone.
No. 2. IS. Loanhead No. 2 Ironstone.
No. 3. IS. Loanhead No. 3 Ironstone.
BB.I. Blackband Ironstone.
CB.I. Clayband Ironstone.
G.IS. Gilmerton Blackband Ironstone.
PN. IS. Penston Ironstone.
J. Johnstone Coal.
JW. Jewel Coal.
K. Kittlepurse Coal.
KB. Kailblades Coal.
L.G. Little Gillespie Coal.
L.SP. Little Splint Coal.
LST. Limestone.
No. 1. LST. Gilmerton Limestone.
No. 2. LST. North Greens Limestone.
No. 3. LST. Bilston Burn Limestone.
No. 4. LST. Index Limestone.
M. Moffats Coal.
N. North Coal.
N.G. North Greens Coal.
P. Peacock or Stinkie Coal.
PN.R. Penston Rough Coal.
PN.SP. Penston Splint Coal.
P.R. Parrot Rough Coal.
PT. Peacocktail Coal.
R. Rough Coal.
R.C. Real Corbie Coal.
S. South Coal.
SH. Stairhead Coal.
SK. Stinkie Coal.
SM. Smithy Coal.
SST. Sandstone.
ST. Stony Coal.
S.W. Siller Willie Coal.
TR.SP. Tranent Splint Coal.
U. Union Coal.
W. Waverley Coal.

The Coal Measures occur in the centre of the basin and extend over an area 9 miles long and $2\frac{1}{2}$ miles in width. Separated by a narrow reef of Millstone Grit, the Carboniferous Limestone Series rises to the west at a high angle, which carries it down to a considerable depth before flattening out under the Coal Measures. When the group emerges to the east, it does so at a gentle angle, so that the Limestone Group, with its coals and cannels, extends over wider areas than in the west.

The most persistent and chief bands of cannel are found in association with the coals of the Limestone Coal Group, and a limited quantity of cannel is still being raised. It is of less frequent occurrence in the Coal Measures.

Cannels and cannel shale—more frequently called 'parrot' and 'parrot shale'—are found at the following horizons in the Carboniferous sequence :—

| | |
|---|---|
| Coal Measures - - - - | Parrot Rough Coal. |
| Upper Limestone Group - - | South or Edmondstone Parrot. |

| | |
|---|---|
| Limestone Coal Group - - | Loanhead No. 3 Ironstone.<br>Great Seam of Niddrie.<br>Stairhead Seam.<br>Loanhead No. 1 and No. 2 Ironstone.<br>Stony Coal.<br>Arniston Parrot Coal. |
| Lower Limestone Group - | Gilmerton Ironstone: North Greens Coal.<br>Crossgatehall Parrot Shale. |

## Lower Limestone Group.

*Crossgatehall Parrot Shale.*—In the railway cutting, three-quarters of a mile N.E. of Crossgatehall, a parrot shale is exposed east of the bridge over the railway. The Lower Limestone Group, with a gentle dip, here extends over a considerable area, and borings three-quarters of a mile to the north-east have shown parrot coal varying from 3 ft. 5 in. to 7 ft. in thickness, so that the parrot shale probably forms an extensive deposit. An analysis by Dr. W. Pollard gave the following percentage composition :—moisture, 7; volatile matter, 32·89; fixed carbonaceous matter, 28·89; ash, 30·76; sulphur, ·85. No commercial tests have been made of this band, but owing to its possible occurrence over a considerable area, it deserves further attention.

The North Greens Coal and Gilmerton Ironstone of the Gilmerton Coalfield (6-in. Edin., 8 N.W.) bear associated cannel.

The Gilmerton Ironstone, 5½ fms. above the North Greens Coal, lies between the Gilmerton Limestone (Hurlet) and the North Greens Limestone. Information regarding the coals is to be obtained from the old Gilmerton workings, and the Gilmerton-Melville diamond bore.

In section, the North Greens Coal is :—

| | Ft. | In. |
|---|---|---|
| Blaes - - - - - - - | — | |
| Parrot Coal - - - - - - | 1 | 4 |
| Hard band - - - - - - | 0 | 6 |
| Fireclay - - - - - - | 0 | 9 |
| Parrot and Rough Coal - - - - | 3 | 0 |

The Parrot Coal, though not of first quality, at one time found a sale.

The Gilmerton blackband ironstone, no longer worked, is separated by fireclay from an underlying parrot coal as follows :—

| | Ft. | Ins. | | Ft. | Ins. |
|---|---|---|---|---|---|
| Blackband - - | 1 | 3 | Blackband - - | 1 | 5 |
| Fireclay - - | 0 | 6 | Fireclay - - | 0 | 4 |
| Parrot Coal - | 1 | 3 | Coarse Parrot - | 1 | 0 |
| Free Coal - | 0 | 8 | Rough Coal - - | 0 | 6 |

In Bilston Burn a rough parrot (2 ft. 6 in.) occurs at 8 fms. above the North Greens Coal and 2 fms. below the North Greens Limestone.

## Limestone Coal Group.

The Arniston Parrot Coal, the lowest coal of the group, is a compound seam of household coal (Jewel Seam of some collieries) and cannel. It is of high quality, yielding on distillation up to 68 galls. of crude oil with 54 lbs. of ammonium sulphate.

On an average this seam of coal is not more than 3 ft. thick, and at Arniston and Newbattle collieries the cannel, lying towards the middle of the seam, varies between 6 and 9 in. in thickness. In the last-mentioned colliery a lateral passage of cannel into a kind of cherry coal is observed. At the Lady Victoria Shaft a section of the seam is :—jewel coal, 1 ft. 3½ in.; parrot coal, 8 in.; bottom coal, 1 ft.; wild coal, 9 in. Further north the cannel part thins away and in the old Cowden Pit is said to be only one inch thick.

The Stony (Parrot and Rough) Coal of Loanhead (6-in. Edin., 7 S.E.) is associated with a varying amount of cannel. At Loanhead the cannel portion is 4 in. thick, and at Burghlee it is up to 15 in. thick and reported to be of high quality. At the Burghlee Pit the coals down to a depth of 1,578 ft. have an average inclination of 58° to the south-east; but at the bottom of the mine the dip decreases to 7° or 5° and continues at this low inclination as far as the coal has been worked eastward. No. 1 Ironstone of Loanhead, 20 fathoms above the Stony Coal, contains about one foot of 'wild parrot' in the middle of the blackband ironstone.

A similar band of the same thickness occurs at Dryden March. A parrot coal, 1 ft. 3 in. thick, was found above a blackband ironstone, 2 ft. thick, in a cross-cut in the Old Square Pit at Gilmerton, and at the Ramsay Pit between a clayband ironstone above and a blackband below. At the Burghlee Pit a 'parrot' in the same position is recorded and also one 10 in. at a distance of 430 fms. to the west.

Loanhead No. 2 Ironstone, situated from 5 to 10 fms. below the Stairhead Coal, has associated cannel in bands from 10 to 18 in. thick.

A wild parrot is also found with the same ironstone in the Burghlee Pit and at Roslin Colliery. This cannel of inferior quality has been tried as a gas producer and reported to be unsatisfactory.

The Stairhead Seam at Niddrie is a compound seam of steam coal, cannel, and blackband ironstone, and used to be mined for its cannel. The seam is worked out to a depth of 350 fms. except to the south between Woolmet and Drum, where only 150–200 fms. have been extracted. Two sections ("The Iron Ores of Scotland," *Mem. Geol. Surv.*, 1920, p. 185) show :—

| | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|
| Steam Coal | 1 | 6 | Coal | 1 | 6 |
| Cannel | 2 | 2 | Cannel | 2 | 0 |
| Blackband ironstone | 0 | 10 | Blackband ironstone | 4 to 0 | 8 |
| Rough Coal (steam) | 1 | 6 | Coal | 1 | 6 |

Tests give a yield of 22 galls. of crude oil per ton on distillation.

A section of the Stairhead Seam on the North British Railway from Portobello East Junction to Niddrie North Junction shows :—

| | Ft. | In. |
|---|---|---|
| Bright Coal - - - - - - - | 1 | 6 |
| Parrot - - - - - - - - | 2 | 0 |
| Bright Coal - - - - - - - | 3 | 0 |
| Parroty blaes - - - - - - - | 0 | 4 |

The Five-foot Coal of Wallyford Colliery has a cannel roof 6 in. thick, but as it forms an excellent roof to the coal, it is left standing in the pit and not brought to the surface. A coarse parrot coal also occurs at Carberry Colliery, 19 ft. above the Five-foot Seam.

The cannel portion of the Great Seam of Niddrie has been, and to some extent is still an important source of cannel.

On distillation the cannel gives up to 51 galls. of crude oil per ton, together with 95·8 lbs. of ammonium sulphate; but, like most of the richer cannels, it has the defect of coking in the retorts. The seam was extensively worked, but thins out both north towards Joppa and south in the direction of Gilmerton, of Niddrie, and also in depth. As with the Stairhead Coal the future of the Great Seam at Niddrie depends upon the saleable value of the cannel, and the prospects of working the seam at great depths, since the high inclination of the beds quickly carries it to rapidly increasing depths towards the centre of the basin.

The section of the Great Seam at Niddrie is :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Coal, unworked - - - | 4 in. | to - | 0 | 9 |
| Cannel or Gas Coal - - | 1 ft. 2 in. | to - | 2 | 6 |
| Ironstone - - - - | 4 in. | to - | 0 | 8 |
| Crow Coal - - - | 3 in. | to - | 0 | 9 |
| Coal - - - - | 1 ft. 2 in | to - | 1 | 6 |
| Daugh or clay - - - | 4 in. | to - | 1 | 8 |
| Bottom coal unworked | - 2 ft. 6 in. | to - | 4 | 0 |

The Great Seam of Newbattle Colliery also contains a band of cannel towards the middle of the seam, but it is much inferior in quality to the cannel of the Parrot Coal of this colliery.

The section of the Great Seam between Portobello East Junction and Niddrie North Junction on the North British Railway is :—Bright coal, 6 ins.; Parrot, good, 1 ft.; Coal, 7 ft.

In the East Lothian Coalfield the Great Seam is without any associated cannel.

In the Loanhead field a coal called the Rumbles Coal has been practically exhausted both for the associated No. 3 Ironstone of Loanhead and the much valued cannel from $5\frac{1}{2}$ to 8 in. in thickness.

Mr. T. Robertson ('Iron Ores of Scotland,' *Mem. Geol. Surv.*, 1920, pp. 186–7) states that 'The Wild Parrot or Rhums above the ironstone is fairly persistent, and if it were used for gas-producing purposes, *e.g.*, in a producer plant, the ash might

possibly be smelted as an iron ore. A commercial analysis of this bed gave as follows ' :—

*Proximate Analysis of the Rhums.*

| | |
|---|---|
| Volatile hydrocarbons | 40·79 per cent. |
| Fixed carbon | 19·28 ,, |
| Ash | 35·51 ,, |
| Moisture | 4·42 ,, |

*Analysis of Ash of the Rhums.*

| | |
|---|---|
| $Fe_2O_3$ | 70·83 per cent. |
| CaO | 3·71 ,, |
| MgO | 0·73 ,, |
| Insoluble | 15·79 ,, |
| S | 0·35 ,, |
| P | 0·64 ,, |
| Total iron | 49·53 ,, |

Locally, at Newtongrange (6-in. Edin., 8 S.E.) a thin ironstone, about 25 ft. below the Index (No. 4) Limestone, contains two cannel bands aggregating 10 in. in thickness. Other bands of cannel occur sporadically in the Limestone Coal Group, especially in the Loanhead and Penicuik districts, but information is lacking regarding their value as oil producers. As they are generally described as ' wild parrots,' they are probably inferior in quality to the seams already referred to.

## Upper Limestone Group.

The Edmondstone or South Parrot of the Niddrie and Loanhead areas is a first-class cannel, part of a compound seam. The cannel portion varies from 5 in. to 1 ft. 3 in. in thickness. On distillation it yields up to 56·5 galls. of crude oil per ton, with 73 lbs. of ammonium sulphate. It cokes in the retort.

The following afford sections of the seam :—

*Niddrie No. 13 Pit.*

| | Ft. | In. |
|---|---|---|
| Splint | 1 | 10 |
| Parrot | 1 | 0 |

*Edgefield.*

| | | |
|---|---|---|
| Parrot | 1 | 3 |
| Free | 0 | 10 |

*Mavisbank.*

| | | |
|---|---|---|
| Fine Splint | 1 | 4 |
| Parrot | 0 | 5 |
| Rough Rich | 1 | 3 |

The band of parrot at Mavisbank was a gas coal of good quality and was sold, together with the upper and lower portions, for household purposes. At Edgefield the parrot was also an excellent gas coal, one ton producing 11,454 cub. ft. of gas of 30 candle-power. On both sides of the Bilston Burn the crop

can be traced by the old workings extending to the top of the wooded bank.[1]

A parrot, 10 to 12 in. thick, is exposed in Hare Burn, half a mile south of Penicuik House. About the year 1866 it supplied cannel for the gasworks at Penicuik House, but was found to be poor in quality.

The position of the South Parrot may be represented on the east side of the basin by a parrot shale from 6 to 10 in. thick seen in the old Cowden Cleugh quarry. A specimen analysed in the Survey laboratory by Dr. Pollard showed :—moisture, 6·07; volatile matter, 49·62; fixed carbonaceous matter, 25·44; sulphur, 1·68; ash, 19·07.

A shale or 'wild parrot,' 14 in. thick, but of which no particulars are available, occurs in conjunction with an ironstone in the Lady Victoria Shaft at Newtongrange, 219 ft. below the No. 5 Limestone.

Underlying the 'Extra Limestone,' a rough cannel appears locally at the junction of the Dryden and Bilston burns.

### Lower Coal Measures.

A band of parrot shale, 7 in. thick, occurs in the middle of the Parrot Rough Coal at Whitehill and Polton. It was formerly distilled, and is stated to have yielded 40 galls. of crude oil per ton.

## 2. CENTRAL COALFIELD.

The wide area of Carboniferous rocks here termed 'Central Coalfield,' includes not only the whole of the great Lanarkshire coal-basin, but also the structurally related coal mining districts in the adjacent counties of Stirling, Renfrew, Linlithgow, Dumbarton and Edinburgh. The Lanarkshire coal-basin constitutes more than 50 per cent. of the total area of about 1,700 sq. miles.

The Carboniferous succession is as follows :—

Barren Red Measures.
Productive Coal Measures.
Millstone Grit.
Upper Limestone Group.
Limestone Coal Group.
Lower Limestone Group.
Calciferous Sandstone.

Cannels and gas coals have long been wrought in the Central Coalfield. The cannels are on the whole much thinner than those of the east of Scotland, and the ready sale which they once commanded was due mainly to favourable economic conditions. The better seams, now practically exhausted, are of little more than historic interest, and the others are so thin

[1] 'The Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 1910, p. 236.

that they hardly can be considered as constituting an appreciable reserve. Carbonaceous deposits of this description occur throughout the succession, except in the Calciferous Sandstone Series. Individual seams and beds were known under various trade-names taken from the names of pits and collieries, and now mostly forgotten.

### Lower Limestone Group.

The only bed of any consequence lies near the summit of the group, and is known as the Lillies or Johnstone Shale Coal of the Paisley district. It was worked from 1870 to 1886, and supplied all the Renfrewshire oil works. Any reserves left cannot be considerable.

The Lillies or Johnstone Shale Coal of the Paisley district lies among the Hosie limestones near the top of the group. It averages 2 ft. in thickness, made up of a foot of coal resting upon a foot of 'shale,' each of these occasionally increasing to 20 in. It was extensively wrought to the north of Johnstone (Milliken and Clippens) and also at Linwood, Blackstone, and Walkinshaw. The variations of thickness recorded in the workings show :— coal, 9 to 20 in.; shale, 11 to 20 in.

The detailed section on the plan of the Blackstone workings (abandoned in 1901) is as follows :—

| | Ft. | In. |
|---|---|---|
| Blaes | — | |
| Ironstone | 0 | 1 |
| Fireclay | 0 | 4 |
| Coal | 1 ft. to | 1 4 |
| Shale | 1 ft. to | 1 5 |
| Blaes | — | |

Two areas where the Shale Coal is as yet untouched may be mentioned. The first 'lies north of Linwood, between Middleton and Blackstone House. Here, from the outcrop down to a depth of about 80 fms., there is about half a square mile in which only one small trial has been made :—a pit having been sunk at a point 500 yds. N.W. of Middleton farm-house, 41 fms. to the shale; but so many "wants" were encountered that the attempt was abandoned. This adverse feature is probably quite local, and the field may well be worth further exploration. The largest extent of unworked ground lies west of Inchinnan. Here the seam occupies a basin, extending over a square mile from its outcrop down to the deepest part south of Bottom farm-house, where it must lie at a depth of 70 fms. Two bores have been put down in this basin, one of which (in 1869) south of Greenhead, found 1 ft. of coal and blaes resting on 22 in. of oil-shale, at a depth of 35 fms.; the other—at the point where the road to Allans leaves the main highway—got 23 in. of shale at the same depth : in both these bores the overlying coal was in two leaves, separated by a 40-ft. bed of sandstone. The shale is thicker here than at Clippens, as is also the case at Walkinshaw, not far to the south, where the coal and shale measured 16 in.

'The yield of oil from the shale in the Clippens and Milliken workings was 40 gallons or more per ton. As regards sulphate of ammonia, we have no figures, but few of these "parrot" shales yield more than 20 lbs. per ton.'[1]

As a thin coal of no economic value it has been proved over a large area of the Central Coalfield. In the Campsie area it is an inferior parroty shale.

### Limestone Coal Group.

Though cannel is commonly associated with the blackband ironstones and coals of this group, it occurs generally as ribs, or in irregular thin layers. The blackband ironstones,[2] moreover, are approaching exhaustion, and it is not a commercial proposition to work cannel alone.

The well-known Lesmahagow Main Gas Coal,[3] which used to be the standard of comparison in the classification of the Scottish cannels and gas coals for trade purposes, is now practically exhausted. It was extensively worked in the Crossford–Auchenheath district, where it was locally associated with a thin blackband ironstone. Near Crossford the coal varies from 5 to 20 in. At Auchenheath it averaged 18 in. The Wee Gas Coal or Auchenheath Oil Coal lies 11 or 12 fms. above the Main Gas Coal. It appears to be confined to a limited area in the Auchenheath and Blackwood district. It varies in thickness from 1 to 12 in., and has generally a band of blackband ironstone 3 to 5 in. thick at its base. It was considered a first-class gas coal, but was still more valued as a 'paraffin oil coal, second only in quality to the Boghead Coal'[4]. The oil yield is stated to have reached 95 gallons per ton. Its interest is only historic.

In the Wilsontown district, the seam known as the Wilsontown Gas Coal, has been extensively worked at Haywood, Cleugh, and Wilsontown, where it is almost exhausted. In the old Cleugh Pits, Wilsontown, the seam lies 8 to 10 fms. below the Black Metals, and showed gas coal 9 in. to 1 ft. 8 in., resting on a blackband ironstone, 2 in. to 5 in. thick.

In the Glasgow and Paisley districts the Limestone Coal Group has been divided into (1) a lower sub-group (Garscadden) with only a few coals; and (2) an upper sub-group (Possil) with several valuable coal seams with which cannels and

---

[1] 'The Economic Geology of the Central Coalfield of Scotland' Area IV, Paisley, Barrhead, Renfrew. (*Mem. Geol. Surv.*), 1920, pp. 37–38.

[2] For sections of ironstones and associated parrots see 'Iron Ores of Scotland' (*Mem. Geol. Surv.*), 1920, pp. 57–133.

[3] For details see 'Economic Geology of the Central Coalfield of Scotland' Area IX, (*Mem. Geol. Surv.*), 1921, pp. 47–50.

[4] Greenshields, 'Annals of Parish of Lesmahagow,' 1864.

blackband ironstones are frequently associated.[1] A very common association is—

Parrot or gas coal.
Blackband.
Parrot or gas coal.
Free coal.

In Linlithgowshire, the Limestone Coal Group contains beds of cannel in association with the following coals :—

Balbardie Gas Coal.
Lower Parrot and ironstone.
Six-foot Seam.
Jewel Coal.

At Bathgate, the Jewel Coal, 25 fms. below the Index Limestone, contains a bed of cannel from a few inches up to one foot thick at the bottom of the coal, and for this reason was sometimes named the Big Parrot Coal. Even at Bathgate the bed is lenticular and it is absent in the ground to the south and west.

The Six-foot Seam of Kinneil is said to have a band of excellent parrot, 8 in. thick, at the bottom of the coal. In the eastern part of the coalfield, however, the seam is known as the Foul Coal and is unworkable.

Only a short distance above the Six-foot Seam the Lower Parrot and ironstone has been extensively worked in the Bo'ness district. Underneath the sea, opposite the harbour and dock, the seam in the workings of the Schoolyard Pit gave the following section :—

| | | | Ft. | In. |
|---|---|---|---|---|
| Common Coal | 3 in. | to | 0 | 10 |
| Parrot Coal | 1 ft. 3 in. | to | 1 | 7 |
| Blackband ironstone | 3 in. | to | 0 | 10 |

The Balbardie Gas Coal of Bathgate was once well known for the high quality of its cannel, 7 in. thick, but now practically exhausted. A boring at Easton Colliery gave the following section of the Balbardie Gas Coal :—

| | Ft. | In. |
|---|---|---|
| Wild Gas Coal | 0 | 3 |
| Cannel Coal | 0 | 7 |
| Ironstone | 0 | 3 |
| Fireclay | 1 | 10 |
| Free Coal | 1 | 6 |

### Upper Limestone Group.

Only one occurrence of a gas coal, known as the 'Climpy Gas Coal,' is recorded. It lies 9½ fms. above the Index Limestone in the Wilsontown field, where it was wrought to a small extent at Climpy. It was too thin (5–8 in.) to be a profitable subject.

[1] For sections showing thicknesses *see* 'Iron Ores of Scotland' (*Mem. Geol. Surv.*), 1920, pp. 68–82.

## Productive Coal Measures.

The principal horizons of cannel are in association with the following coals in descending order :—

Splint Coal.
Virtuewell Coal.
Kiltongue Musselband Shale, Shale Coal.
Craw or Gas Coal of Falkirk.
Shotts Gas Coal.
Mill Coal.
Torbanehill or Boghead Cannel Coal.

The Torbanehill or Boghead Cannel Coal is found only over a small area in the Armadale district. It was worked from about 1850 to 1862 until the field was exhausted. A little is still occasionally got just beyond the limits of the worked area during exploitation of the Colinburn Coal which closely overlies it. It has mainly a historic interest, but prior to the workings of the Lothian Shales was in great demand. Its yield of oil was as much as 120 gallons per ton. In no other district is a cannel found at this horizon.

The Mill and Shotts Gas coals locally (*e.g.*, in the Shotts area) contain a considerable proportion of gas coal and were formerly in great demand on this account.

The Craw (Crow) Coal of the Falkirk area, possibly corresponding to the Kiltongue Coal of Lanarkshire, is generally present over the central part of the district, but is only about a foot in thickness. It is a compound seam of gas coal and ironstone, giving the following section at Crosscroes :—

| | Ft. | In. |
|---|---|---|
| Fakes | 1 | 3 |
| Blaes | 1 | 10 |
| Gas Coal | 0 | 8 |
| Gas Coal and ironstone | 0 | 9 |
| Ironstone | 0 | 5 |
| Blaes | — | |

An analysis of the seam at East Roughrigg, made by Mr. G. R. Hislop in 1890, showed 46 per cent. of volatile matter.

The Kiltongue Musselband Shale and ironstone occurs over the whole of the Central Coalfield and has been worked for oil, and also been tried as a possible source of iron. It lies towards the middle of the Productive Coal Measures, a few fathoms above the Kiltongue Coal. An average section shows :—

| | Ft. | In. |
|---|---|---|
| Dark parroty blaes | 1 | 6 |
| Tough shale or Cannel | 0 | 4 to 9 |
| Shale with 'mussels,' often irony | 0 | 8 |
| Ironstone | 0 | 2 |
| Fireclay or blaes | — | |

The seam has been worked for the extraction of oil in the Rawyards Clarkston area, where it is said to have yielded 30 galls. of oil per ton, the chief localities being Rochsoles, Ryden,

Raebog, Glenmavis. It was also wrought in the Greengairs–Longriggend field at West Glentore, Greendykeside, and Arden; in the Larkhall district at Swinhill, Kittymuir, and Birkenshaw, where the yield was 23 galls. a ton. Attempts to work the shale were also made on a small scale at Southfield, in the Slamannan district.

A trial pit just south of Glenmavis is reported to have given the following section[1] :—

| | Ft. | In. |
|---|---|---|
| Blaes | 3 | 0 |
| Ironstone balls, rich but irregular | 0 | 4 |
| Good Shale | 1 | 6 |
| Parrot Coal, very rich | 0 | 2 |
| Musselband ironstone | 0 | 9 |
| Ironstone balls | 0 | 1½ |
| Fireclay | — | |

In the Falkirk field, the Kiltongue Musselband appears to be represented by the Miller or Carron Two-foot Coal, which is generally present over the area, and sometimes, as at Pirleyhill Bridge, is associated with an oil-shale having a thickness of 22 in., and a yield (from analyses by Mr. D. R. Steuart) as follows :—

| | *Oil.* | *Ammonium Sulphate.* |
|---|---|---|
| Top sample | 25·47 galls. per ton. | 12·54 lbs. per ton. |
| Centre sample | 14·86 „ „ | 4·18 „ „ |
| Bottom sample | 11·65 „ „ | 8·36 „ „ |

At Coneypark, the Shale Coal, 6 fms. above the Kiltongue Coal, has been very extensively worked. As the following section shows, an oil shale is associated with it and was formerly taken out along with the coal :—

| | Ft. | In. |
|---|---|---|
| Black blaes | 2 | 2 |
| Oil Shale | 0 | 5 |
| Ironstone | 0 | 7 |
| Coal | 1 | 1 |

In the Banknock field the section of the seam is :—

| | Ft. | In. |
|---|---|---|
| Musselband Ironstone | 0 | 1½ |
| Oil Shale | 0 | 9 |
| Musselband Ironstone | 0 | 5 to 8 |
| Black blaes | 0 | 3 to 8 |
| Coal | 20 in. to 2 | 8 |
| Fireclay | — | |

In the Wishaw district the horizon is well exposed along the Garrion Burn, the most easterly being in the neighbourhood of Gillhead Bridge. An average section is :—

| | Ft. | In. |
|---|---|---|
| Thick sandstone | — | |
| Dark shaly blaes | 1 | 5 |
| Cannel Shale | 0 | 4 to 6 |
| Musselband Shale | 0 | 8½ |
| Clayband ironstone | 0 | 2 |
| Fireclay | 3 | 6 |

[1] 'The Economic Geology of the Central Coalfield of Scotland,' Area V, (*Mem. Geol. Surv.*), 1916, p. 94.

The cannel shale is tough, with a dull lustre; 'curls' readily and has a brownish streak.

The Virtuewell Coal has generally a thin shale roof. This shale has been locally found rich enough and of sufficiently good quality to be worked along with the coal. It is best developed in the districts of Slamannan, Longriggend, Greengairs and Rawyards, where it varied from 5 to 15 inches, and was formerly taken out along with the coal and used for gas making as well as a source of oil. The Virtuewell Coal, 2½ to 3 ft. thick, is now practically exhausted. In the Motherwell area a thin parrot shale occurs as a roof to the Virtuewell Coal and was formerly used for the distillation of oil. The old Stanrigg Oil Works, between Airdrie and Longriggend, were set up to treat this shale.

The Splint Coal, now approaching exhaustion, characteristically contains a band of gas coal of variable thickness, varying between 4 in. and one foot.

The following represent some typical sections :—

*Bent Colliery, Hamilton.*

| | Ft. | In. |
|---|---|---|
| Free Coal | 0 | 4½ |
| Splint Coal | 1 | 8½ |
| Gas Coal | 0 | 7 |
| Free Coal | 1 | 3 |
| Parting | 0 | 0½ |
| Free Coal | 1 | 8 |
| Parting | 0 | 3 |
| Foul Coal | 1 | 2 |

*Eddlewood Colliery.*

| | | |
|---|---|---|
| Splint Coal | 1 | 11 |
| Gas Coal | 0 | 9 |
| Free Coal | 2 | 10 |
| Parting of fireclay | 1 | 0 |
| Free Coal (Virgin) | 1 | 0½ |

A little farther east the Splint and Virgin coals unite and at Home Farm Colliery furnish the following section :—

| | Ft. | In. |
|---|---|---|
| Sandstone | — | |
| Blaes | 2 | 6 |
| Coaly blaes | 0 | 7 |
| Free Coal | 0 | 9 |
| Splint Coal | 1 | 5 |
| Free Coal | 0 | 6 |
| Gas Coal 1 ft. to | 1 | 7 |
| Free Coal | 1 | 1 |

The presence of gas coal as a constituent of the Splint Coal is also typical of the Bothwell-Uddingston area, *i.e.*, at Greenfield, Hamilton Palace, Viewpark, Tannochside. In part of the Bredisholm field it was distilled for oil, the yield being about 32 galls. per ton.

## 3. DOUGLAS COALFIELD.

This area of Carboniferous rocks, continued as a narrow strip up the Douglas Water, forms a distinct geological unit. It is separated from the Central Coalfield by the belt of Old Red Sandstone that runs from Lesmahagow to Lanark. Rocks of the same age separate it from the Muirkirk–Glenbuck basin, though the names given to the principal coals are for the most part common to the two fields.

### Limestone Coal Group.

On the west side of the basin, in the Coalburn district, the group is from 55 to 66 fms. thick; but where it reappears at the surface on the east at Ponfeigh and Rigside, it is nearly twice as much. On the west side the nomenclature of the coals is common to the Muirkirk–Glenbuck Coalfield, while a local nomenclature is in use on the east side :—

| *Coalburn Area.* | *Ponfeigh Area.* |
|---|---|
| Seven-foot Limestone. | Index Limestone. |
| Smithy and Dross Coal. | Wee Drum, Big Drum coals. |
| Ell or Four-foot Coal. | Skaterigg Coal. |
| Nine-foot or Splint Coal. | Kirkroad, Stony coals. |
| Thirty-inch Coal. | Back Coal. |
| Six-foot Coal. | Robb, Fallowhill and Stoneypath coals. |
| Macdonald Coal. | Wood or Smithy Coal. |
| Top Macdonald Limestone. | Top Macdonald Limestone. |

The Six-foot Coal represents the Lesmahagow Main Gas Coal. It contains a rib of cannel about 6 in. thick, yielding on distillation 52 galls. of crude oil per ton.

The Nine-foot or Splint Coal also carries a bed of cannel of about the same thickness, which yields 34 to 37 galls. of oil per ton. The Wee Drum Coal is separated by a variable parting from a coal below, named the Big Drum, which contains a very irregular bed of cannel varying from a few inches up to 2 ft. 6 in. in thickness.

### Upper Limestone Group.

There are probably some reserves of the Ponfeigh Gas Coal, which is a compound seam containing up to 1 ft. 8 in. of rich cannel. An analysis for gas-making purposes showed 53·81 per cent. of volatile matter.

### Lower Coal Measures.

A seam in the Lower Coal Measures recently met in a cross-cut at Douglas Castle Colliery, was found, at the place where cut, to contain a band of cannel 2 ft. 3 in. thick, which on a distillation test has yielded 47·1 galls. of crude oil per ton.

## 4. FIFESHIRE COALFIELD.

The Fifeshire Coalfield, with an area of roughly 170 square miles, presents the same general Carboniferous succession as the Central Coalfield, but the Limestone Coal Group is richer in coal and the Upper Limestone Group also contains some workable seams. In Eastern Fifeshire the Calciferous Sandstone Series furnishes two workable seams of coal.

In Central and Western Fifeshire, the Lower Carboniferous rocks are involved in a main basin-fold, split up by faulting and folding into minor basins, of which those of Dunfermline, Lassodie, Kelty, Lochgelly, and Kirkcaldy are the most important. Igneous intrusions in the form of sills and bosses, but less frequently as dykes, abound, and volcanic eruptions were very active during the deposition of the upper part of the Calciferous Sandstone Series and later.

Cannel and allied substances are found separately or in association with the seams of coal, in each subdivision of the Carboniferous succession.

### Calciferous Sandstone Series.

A few thin seams of cannel of poor quality and thin beds of oil-shale occur in these strata, but, with one exception, they are too poorly developed to have any commercial value.

At Muiredge, near Pitcorthie, 2 miles north of Anstruther, a compound seam of true oil-shale, blackband ironstone, and irony parrot coal was worked for a short period about the year 1870. It is nowhere exposed, and we are indebted to Mr. J. Gemmell for the following section :—

| | Ft. | In. |
|---|---|---|
| Blaes and limy blaes | 0 | 9 |
| Oil Shale - 10 in. to | 1 | 1 |
| Limestone fakes | 2 | 0 |
| Brown irony limestone - 5 in. to | 0 | 6 |
| Blackband ironstone | 0 | 5 |
| Irony parrot coal | 0 | 9 |
| Daugh holing | 0 | 3 |
| Coarse fireclay with hard balls 1 ft. 3 in. to | 2 | 0 |
| Foul coal | 0 | 7 |

The shale portion yielded from 20 to 25 galls. of oil of good quality per ton. Work was abandoned owing to the failure of the local supply of cheap fuel. Of recent years search for more remunerative seams was made by boring in the same district, but without success.

### Lower Limestone Group.

A syncline of these strata stretches from Denhead across Mount Melville to Lumbo, near St. Andrews. The inclination of the rocks is steep, the angle of dip often reaching 40°. A band of parrot coal, 5 in. thick, is here associated with the Denhead Ironstone in a stratigraphical position between the basal limestone of the group and a limestone known locally as the Five-foot Limestone.

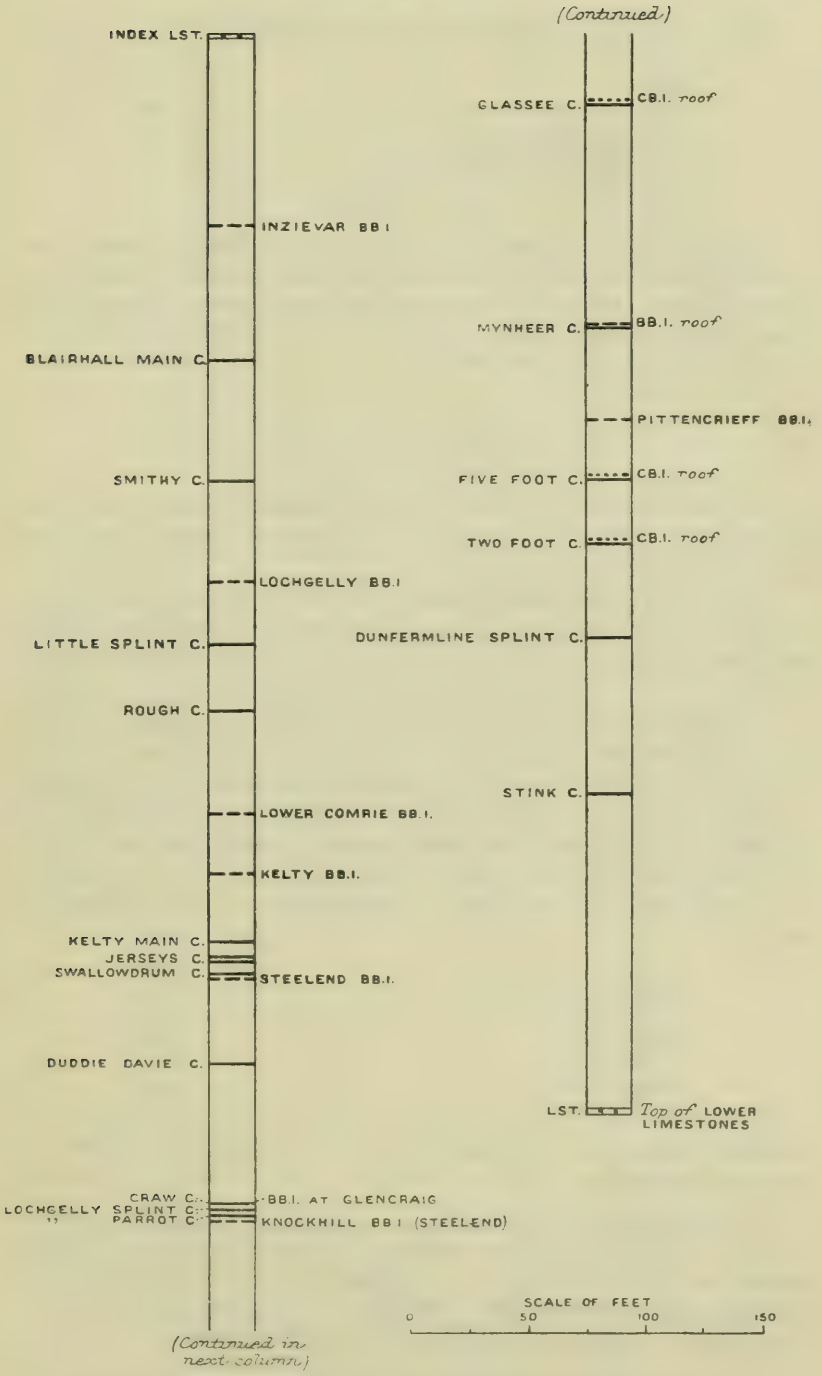



FIG. 2.—General Succession of the Coals and Ironstones in the Limestone Coal Group of Western and Central Fife.

C. = Coal. BB.I. = Blackband ironstone.
CB.I. = Clayband ironstone. LST. = Limestone.

The composition of the seam at Lumbo was :—

| | Ft. | In. |
|---|---|---|
| Shale | — | |
| Parrot coal | 0 | 5 |
| Coaly shale and coal streaks (Rums) | 1 | 1 |
| Brown stone (ironstone) 5 in. to | 0 | 7 |
| Coal (cherry) | 1 | 6 |
| Shale | — | |

In the journal of the Elgin Bleachfield bore ('Geology of Central and Western Fife and Kinross,' *Mem. Geol. Surv.*, p. 49) a seam, noted as irony parrot coal or blackband ironstone, 1 ft. thick, occurs 16 fms. below the Charlestown Limestone and at a depth of 51 fms. from the surface.

## Limestone Coal Group.

Between the top of the Lower Limestone Group and the Index Limestone this important coal-bearing group attains an average thickness of 1,100 ft.

Below the Dunfermline Splint Coal, 200 ft. above the base of the group, borings have shown the occasional presence of thin seams of coarse or inferior cannel, not associated with workable coals.

One of the seams, said to be 14 in. thick, was worked long ago at Drumcarrow, 4 miles south-west of St. Andrews.[1]

In the Rameldry coal-basin, one mile south-east of the village of Kettle, where the Limestone Group is brought down by a fault against the Calciferous Sandstone Series, a parrot coal, said to be 4 ft. 2 in. thick, including 2 in. of soft coal, has been reported to occur low down in the group in connection with the following coals :—

| | Ft. | In. |
|---|---|---|
| Upper & Main Coal | 3 | 6 |
| Measures | 60 | 0 |
| Smithy Coal | 1 | 9 |
| Measures | 24 | 0 |
| Parrot Coal | 4 | 2 |
| Measures | 60 | 0 |

Locally, it has lost its volatile matter through the action of igneous intrusions.

At Largoward, cannel coal is stated by Landale (*op. cit.*, p. 306) to form the lower stratum of a bituminous bed, locally known as 'pelt and rum.' A parrot coal is also said to occur at the top of the Largoward sequence. The thickness given is 2 ft., but it is not stated whether it is wholly cannel.

[1] D. Landale, 'Report on the Geology of the East of Fife Coal Field.' *Prize Essays, and Transactions of the Highland and Agricultural Society of Scotland.* Vol. XI, 1837, p. 322.

Above the Dunfermline Splint, cannel occurs in the following positions, in association either with the coal or ironstone named :—

| | Ft. | In. |
|---|---|---|
| Index Limestone | — | |
| Measures | 125 | 0 |
| Inzievar or Blairhall Ironstone | — | |
| Measures | 150 | 0 |
| Lochgelly Blackband Ironstone | — | |
| Measures | 170 | 0 |
| Swallowdrum Coal | — | |
| Measures | 100 | 0 |
| Lochgelly Parrot Coal | — | |
| Measures | 75 | 0 |
| Glassee Coal | — | |
| Measures | 90 | 0 |
| Mynheer Coal | — | |
| Measures | 40 | 0 |
| Pittencrieff or Elgin Ironstone | — | |
| Measures, with Five-foot and Two-foot coals | 90 | 0 |
| Dunfermline Splint Coal. | | |

The Pittencrieff Ironstone is of local occurrence and not now of economic importance, but is at times associated with some cannel.

The Glassee Coal, which is generally a house or a steam coal, locally contains in the Lochgelly district from 14 to 21 in. of cannel, which is separated and sent to gasworks.

The Lochgelly Parrot Coal contains intercalations of cannel, occasionally up to 3½ ft. thick, but as a rule the thickness is between 1 and 10 in. The yield of oil is about 34 galls. per ton; sulphate of ammonia, 57 lbs. per ton.

The following section gives the composition of the Parrot Coal in the Cowdenbeath district[1] :—

*Cowdenbeath Colliery.*

| | Ft. | In. |
|---|---|---|
| Foul Coal | 2 | 0 |
| Splint Coal | 5 | 0 |
| Fireclay | 1 | 0 |
| Coal | 0 | 9 |
| Parrot Coal | 2 | 0 |
| Coal | 1 | 3 |

The Swallowdrum Coal, at Muircockhall Colliery, in the Dunfermline district passes into cannel, which was greatly esteemed as a gas producer, but is now largely wrought out. At Halbeath, the seam consists of an upper rough coal, 1 ft. 2 in., separated by 9 in. of fireclay from a lower part of parrot coal, 1 ft. 10 in. thick. An analysis by Mr. G. R. Hislop gave 47·41 per cent. of volatile matter.

The Lochgelly Ironstone, over most of the Lochgelly field is a compound seam of blackband ironstone and shale. The shale varies up to 16 in. in thickness, and where richest, has given

[1] 'The Geology of Central and Western Fife and Kinross' (*Mem. Geol. Surv.*), 1900, p. 197.

up to 32 galls. of crude oil per ton. In the isolated Kilmux field, about 1½ miles north-east of Kennoway and 3 miles north-west of Leven, an ironstone (most likely on the position of the Lochgelly Blackband) associated with a parrot coal and shale, occurs 2 to 3 fms. below a coal known locally as the Six-foot Coal. The constitution of the ironstone seam is :—

| | In. |
|---|---|
| Fakes | — |
| Free coal | 6 |
| Shale | 4 |
| Parrot coal | 7 |
| Blackband ironstone | 10 |
| Blaes & balls | — |

The Inzievar or Blairhall Blackband, also known as Oakley Ironstone, Upper Comrie or No. 1 Comrie Ironstone, workable only in the extreme west of Fifeshire, near Oakley, is associated with a cannel a few inches thick.

At Blairhall the seam had the following section :—

| | Ft. | In. |
|---|---|---|
| Sandstone roof | — | |
| Parrot coal | 0 | 4 |
| Ironstone (blackband) | 1 | 3 |
| Blaes | 0 | 3 |
| Ironstone (blackband) | 0 | 1 |
| Parroty blaes | 0 | 3 |

## Upper Limestone Group.

Cadell's Parrot, in the extreme west of Fife and in the Lochgelly field, where it is known as the Lochore Parrot, is a well-known cannel, occurring on an average about 25 fms. above the Index Limestone.

In the Blairhall district Cadell's Parrot was long ago worked as cannel. Its waste lies 27 fms. above the top leaf of the Index Limestone.

At Lochore the seam varies from a few inches up to 2 ft. 2 in., and contains ironstone which would be a useful by-product. The seam extends roughly over 600 acres, so that there may be a not inconsiderable reserve. In the Oakley district the indications are that the seam is largely wrought out.

The Lochore Parrot Coal is composed of the following subdivisions :—

| | In. |
|---|---|
| Fakes & fireclay roof | — |
| Coal 'daugh' | 1 |
| Parrot | 11 |
| Ironstone | 1 |
| Coal 'spratt' | 5 |
| Ironstone | 3 |
| Coal 'spratt' | 3 |
| Coal, rough | 3 |
| Fakes and sandstone pavement | — |

The Capeldrae Parrot Coal, not far below the position of the Calmy Limestone, has long been known as a first-class cannel.

It is typically developed in the Capeldrae–Lochore basin, and was systematically worked in the latter half of last century. The more readily accessible portions are supposed to be worked out, but many of the pits were abandoned before exhaustion on account of difficulties due to water. The cannel was sold for the enrichment of gas, and was not used as an oil producer. The seam consisted of two leaves up to 1 ft. 6 in. and 1 ft. 8 in. respectively, of different quality, the best giving on distillation from 70 to 81 galls. of crude oil per ton. The second quality yielded from 41 to 65 galls.

In the Rosewells portion of the Lochore field 'the quality of the Parrot Coal was found to be excellent towards the south, but to fall off in value to the north around Flockhouse, owing to the appearance in it of abundant coprolites and "clay galls," whereby its gas-producing properties were seriously reduced. Here a second gas coal, known as the Wee Parrot, lying 14 fms. below the Capeldrae seam, has been worked to a small extent on either side of the anticlinal fold, along the centre of which it crops. The eastward prolongation of the Capeldrae Parrot Seam to Auchterderran has been proved by numerous borings; but in almost every case it has been found to be either burnt through the effects of the igneous rocks, or it has gone into the poor condition known in mining language as "wild parrot" (The Geology of Central and Western Fife and Kinross, *Mem. Geol. Surv.*, 1900, p. 141).

Though the horizon of the Capeldrae Cannel extends over a large area, the seam has economic value in only one other district, namely, at Oakley, where it is known as Overton or Oakley Parrot, and was wrought extensively. The seam averaged 2 ft. 1 in. in thickness, of which only 10 in. was cannel.

### Lower or Productive Coal Measures.

The Coal Measures of the Dysart, Wemyss, and Leven Coalfield are separated by a considerable thickness of Millstone Grit from the Upper Limestone Group. The Lower (Lanarkian) Coal Measures attain a thickness of nearly 1,600 ft., subdivided as regards the occurrence of cannel coals in the following order :—

*Upper Barren Red Measures.*

| | Ft. |
|---|---|
| Measures with several workable coals | 430 |
| Bush Coal | — |
| Measures | 350 |
| Parrot Coal | — |
| Measures | 37 |
| Wood Coal | — |
| Measures | 37 |
| Pirnie or Earl David's Parrot Coal | — |
| Measures with many coals | 450 |
| Dysart Main Coal | — |
| Measures | 75 |
| Lower Dysart (Seven-foot) Coal | — |

*Millstone Grit Series.*

The Lower Coal Measures of Fife cover a triangular area stretching along the coast from Dysart to Leven and inland to Markinch. On the west their boundary is defined by outcrop; to the north they are faulted against Carboniferous Limestone strata; seawards they dip below the Upper Barren Red Measures and extend beneath the Firth of Forth to connect with the Coal Measures of the Midlothian basin. The portion, including the Limestone Coals, beneath the Firth of Forth is estimated to cover an area of 130 square miles, with the seams of the Coal Measures on the Fifeshire side better developed than on the Midlothian side. Coal is being won undersea opposite Dysart and Leven.

The Lower Dysart Coal contains a band of cannel varying in thickness from 0 to 8 in. It is rich in oil of good quality—up to 90 galls. per ton. The coal is of inferior quality.

At the Sweet Dub Pit, Gallatown, Dysart, the seam has the following composition :—

| | Ft. | In. |
|---|---|---|
| Hard grey stone roof | — | — |
| Coal | 1 | 3 |
| Stone | 0 | 1 |
| Coal | 2 | 4 |
| Fireclay | 2 | 6 |
| Coal, rough | 1 | 8 |
| Coal, parrot | 0 | 8 |
| Coal, rough | 0 | 8 |

Probably corresponding to the Lower Dysart Coal, a seam of coal, at Westfield, north of Auchterderran, is underlain by a bed of oil-shale from 2 ft. 4 in. to 3 ft. 9 in. thick. It was worked for oil-making for a few years in the sixties and again in the eighties of last century, with a yield of crude oil varying from 18·5 to 30 galls. per ton. As the field has not been tested by boring beyond the vicinity of the workings, it is not possible to make an estimate of the reserves, but the seam may possibly extend over the whole of the Kinglassie Coalfield, or about 3 square miles.

The Pirnie or Earl David's Parrot extends over an area of 3 to 4 square miles between West Wemyss and Leven. It also has an unproved extension under the Firth of Forth. Its thickness varies between 1 ft. 2 in. and 4 ft. 6 in. From 1864 to 1868 it was worked at Pirnie and retorted for oil at Methil. The quality of oil was good and the yield from 28 to 74 gallons per ton, with from 30 to 56 lbs. of ammonium sulphate per ton.

In the Victoria Pit, West Wemyss, the bed consisted of :—

| | Ft. | In. |
|---|---|---|
| Shale and bands forming roof | — | — |
| Coal, parrot | 1 | 2 |
| Coal, rough | 1 | 2 |
| Shale pavement | — | — |

The Wemyss Parrot Coal contains a band of cannel in the position shown below :—

| | Ft. | In. |
|---|---|---|
| Sandstone roof | — | |
| Shale | 4 | 0 |
| Black shale | 0 | 4 |
| PARROT COAL | 0 | 5 |
| Black shale | 0 | 4 |
| Stone | 0 | 2 |
| COAL | 2 | 0 |
| Brown stone | 1 | 0 |
| COAL | 0 | 3 |
| Shale | 2 | 9 |

According to Landale the highest seam of the Wemyss district is a coarse parrot coal, 2 ft. 6 in. thick. It is stated to yield gas, but not in such abundance as the other cannels of this field.

## 5. AYRSHIRE COALFIELD.

The known cannel coals of Ayrshire appear, with a single exception, to be confined to two divisions of the geological sequence :—the Limestone Coal Group, and the Lower or Productive Group of the Coal Measures. The exception referred to occurs at Barrmill, where a cannel coal has been worked in the Upper Limestone Group.

### LIMESTONE COAL GROUP.

*A. North Ayrshire.*—At present only one seam containing cannel is being worked in the Limestone Coal Group in this part of the county. This is at Wardend (formerly Wheatrigg) Colliery, near Kilmaurs, where the seam is known as the Gas, or Cannel Coal. The position is 3 fms. below another coal, and 34 fms. below a limestone probably higher in the sequence than the Index or Highfield, which is most likely locally absent. The Gas Coal has been correlated with the Borestone of the Dalry sequence, but this is doubtful. The section is :—

| | Ft. | In. |
|---|---|---|
| Blaes | — | |
| Wild coal | 0 | 2 |
| Fireclay | 2 | 3 |
| COAL | 1 | 7 |
| Parting | 0 | 1 |
| COAL | 0 | 3 |
| Stone | 0 | 3 |
| GAS COAL | 0 | 9 |
| Rib stone | 0 | 3 |
| Fireclay | 0 | 3 |

The seam is of interest as the only one which there was any attempt to use for the distillation of oil for some 10 years prior to the outbreak of war. Distillation had been temporarily discontinued, but was renewed in 1919 by means of a process which

involves the use of superheated steam. Tests by different methods give from 39 to 72 gallons of crude oil per ton, with from 32 to 111 lbs. of sulphate of ammonia.

In the small Caldwell and Uplawmoor coalfields a gas coal about a foot thick lies 2 fms. below the Main Coal of that district. It is said to have been worked at Uplawmoor—on the Renfrewshire side of the county boundary.

In the district to the south-east of Beith a bituminous blaes overlies the Dalry Clayband, and is possibly deserving of some attention, as it is taken out in the clayband workings, and at present accumulates in bings.

The Wee Coal of the Dalry sequence has been worked as a gas coal near Kilbirnie, but it is believed that not much of it remains. A gas coal is stated to have been worked long ago at Langside, to the north of Dalry, but its horizon is not known.

*B. South Ayrshire.*—There appear to have been two localities where gas coal was worked near Sorn. The first of these, mentioned by Dron,[1] was at Dalgain, half a mile to the east of the village, where the section was 1 ft. 8 in. of dross coal, resting on 1 ft. 4 in. of gas coal, separated by 4 ft. 6 in. of sandstone from an underlying worked 'Splint' seam.

The gas coal is said to have been of very good quality. What was possibly the same gas coal was also worked at Laigh Brocklar, about a mile to the north of Dalgain. Some of the gas coal from this district is said to have been distilled for oil.

A somewhat extensive field of gas coal exists, and is at present worked at Muirkirk, though the cannel bands, which occur in two different coal-seams, are in neither case of great thickness.

The horizons are the Seven-foot and Nine-foot coals. In the eastern or Glenbuck portion of the basin, where the Seven-foot Coal splits, a gas coal is included in the upper, or Three-foot division of the seam. Sections (1) of the Seven-foot Coal at Kames, near Muirkirk, (2) of the Three-foot seam at Grasshill, Glenbuck, and (3) of the Nine-foot Coal from Grasshill, are as follows :—

(1)

| | Ft. | In. |
|---|---|---|
| Blaes | — | |
| Wild Gas Coal ('horny') | 0 | 9 |
| Free Coal | 1 | 2 |
| Gas Coal | 0 | 3 |
| Free Coal | 1 | 4 |
| Stone rib | 0 | 4 |
| Free Coal | 2 | 6 |
| Gas Coal | 0 | 4 |
| Free Coal | 1 | 6 |
| Coaly fireclay | 1 | 6 |
| Free Coal | 0 | 11 |
| Wild Gas Coal ('horny') | 0 | 8 |
| Free Coal | 1 | 3 |
| Freestone | — | |

[1] 'Coalfields of Scotland,' 1902, p. 40.

| | Ft. | In. |
|---|---|---|
| (2) | | |
| Blaes | — | |
| Head Coal | 1 | 3 |
| Blaes ('rattler') | 0 | 8 |
| Wild Gas Coal ('horny') | 0 | 6 |
| Free Coal | 1 | 6 |
| Gas Coal | 0 | 5 |
| Free Coal | 0 | 10 |
| Daugh | — | |
| Fireclay | — | |
| (3) | | |
| Blaes | — | |
| Free Coal | 2 | 6 |
| Gas Coal | 1 | 3 |
| Free Coal | 0 | 5 |
| Stone rib | 0 | 1 |
| Free Coal | 1 | 2 |
| Stone rib | 0 | 2 |
| Free Coal | 1 | 5 |
| Stone rib | 0 | 6 |
| Free Coal | 0 | 6 |
| Fireclay | 0 | 6 |

The gas coal in the Nine-foot seam, however, is not everywhere so thick.

A seam of very rich gas coal, 7 in. thick, has also been worked at Glenbuck, 6 fms. above the Three-foot.[1]

The 'Clay Gas Coal' formed the highest worked seam in the little syncline named the 'ship,' at Guelt, 3 miles north-east from New Cumnock, and is said to have been a brown cannel of exceedingly fine quality. A band of gas coal also occurred in one of the other seams of the Guelt section.

A seam named the 'Parrot' or 'Sulphury Coal' forms one of the limestone coals of the Dailly basin, and parrot is also found in connection with the Craigie Seam, but the only cannel coal mined in this district at present is a thin band in the Main Coal. The quantity is exceedingly limited, but a test of the material gave 46 galls. of oil per ton, with 37 lbs. of sulphate of ammonia.

### Upper Limestone Group.

A gas coal occurred 9 fms. above the Highfield or Index Limestone at the Barr and Gatend collieries, to the south-west of Barrmill, but has been all taken out.

### Lower or Productive Coal Measures.

*A. North Ayrshire.*—Cannel coals or oil-shales occur at the following horizons, in descending order, in the Coal Measures of northern Ayrshire :—

McNaught Coal.
Tourha' Coal.
Major Coal.
Linn Bed.

[1] *Op. cit.*, p. 33.

Parrot Coal (of Stevenston, &c.).
Parrot Shale, or Shale Coal.
Ell Coal.

At Auchenharvie, to the east of Saltcoats, the Ell Coal consists of 15 in. of free coal underlying 10 in. of 'parrot,' and the seam was at one time locally known as the Little Parrot. The cannel is, however, of local occurrence, as it does not extend as far as Kilwinning, nor has it, so far as is known, been found on this horizon in any other part of northern Ayrshire.

The Parrot Shale, or Shale Coal was in former years the most important seam in northern Ayrshire from the point of view of distillation of oil. It was wrought, and oil works were erected for its treatment, between Stevenston and Kilwinning, at Fergushill (near Montgreenan), and in the neighbourhood of Doura and Annick Lodge.

The Annick Lodge oil-works, the last in operation, was closed down about 15 years ago. Ammonium sulphate was obtained as well as oil, but the latter was only from 14 to 20 galls. per ton, and had to be taken to a Lothian refinery. Even under these adverse circumstances the enterprise was financially a success.

Where best developed, the seam consists of about a foot of shale, overlying a similar or somewhat greater thickness of free coal, which is a good steam coal at Fergushill. The horizon is clearly indicated in a good many bores, which have been put down between the Doura and Annick Lodge area and Kilmarnock, and it has been worked to some extent in this district, but close to Irvine it is probable that the seam has been largely destroyed by igneous intrusions. East of Kilmarnock, though the coal can be recognised in places, the shale seems to be absent. Analyses of the shale give from 24 to 31 per cent. of volatile constituents, with from 44 to 59 per cent. of ash. A recent test of the material from Fergushill gave 54 galls. of crude oil per ton, with 49·9 lbs. of sulphate of ammonia, while another from Annandale, near Kilmarnock, gave 37 galls. and 20 lbs. respectively. There is, undoubtedly, a large area of this seam to work, as none of the past workings have been very extensive.

The Parrot Coal is known by that name from Saltcoats to some distance east of Irvine, though further east it is named the Splint, or forms the upper part of the Hurlford Main Coal. Where it is called the Parrot it very commonly contains a band of cannel coal, a section at Auchenharvie, near Saltcoats, being as follows :—

| | Ft. | In. |
|---|---|---|
| Fireclay | — | |
| Coal | 0 | 8 |
| Stone | 0 | 1 |
| Coal | 2 | 6 |
| Parrot | 0 | 8 |
| 'Clach' | 0 | 4 |
| Coal | 0 | 4 |
| Freestone | — | |

The 'clach' is an inferior parrot, replaced in some sections by 'daugh' or by clay. The parrot was formerly used for gasworks, though in some workings it has been left under ground for a long time. An analysis of this portion from Fergushill gives 37·10 per cent. of volatile matter, with 12·39 per cent. of ash.

The Linn or Linnie Bed is a thin coal which occurs a few fathoms above the Parrot Coal, or top of the Hurlford Main, over part but not all of the North Ayrshire Coalfield, and in some places contains cannel. A sample of the latter from Gauchalland gave 34·20 per cent. of volatile matter, with 12·31 per cent. of ash.

The presence of cannel in the Major Coal appears to be rather exceptional, though a foot of it occurs in the upper part of the seam at Burnbank, and a layer of cannel from the Major at Gauchalland gave 34·24 per cent. of volatile matter, with only 2·72 per cent. of ash.

A black bituminous shale almost constantly overlies the Tourha' Coal, through the whole of northern Ayrshire, and measures from 3 ft. to 8 ft. in thickness. An attempt at distillation was made some 40 or 50 years ago at Hurlford, but though 30 galls. of oil per ton are said to have been got, the venture does not appear to have been a success. An analysis of the shale from Windyedge Pit, west of Kilmarnock, gives 14·06 per cent. of volatile matter, with 57·96 per cent. of ash.

A cannel is occasionally found about a fathom below the McNaught Coal.

A gas coal in the Coal Measures was wrought long ago at Adamhill, on the northern margin of the Mauchline basin. The outcrop is shown on the six-inch Geological Survey Map (Ayr 23), but no details have been obtained with regard to this occurrence.

*B. South Ayrshire.*—The most important development of cannel coal in the Coal Measures of southern Ayrshire is in the small, half-detached basin of New Cumnock. Here two seams containing cannel have long been known, either as the Lanemark and the Boig, or as the Upper and Lower Gas coals, while they are at present named the Main Cannel and Five-foot coals in the workings of the New Cumnock Colliery Co. The lower or Five-foot Coal has a section consisting of about 6 in. of cannel resting on 4 or 5 ft. of free coal, and an analysis of the cannel gives 27·2 per cent. of volatile matter, with 6·6 per cent. of ash. A good deal of this seam is still unwrought. The Upper or Main Cannel seam was, however, by far the more important at the period when gas coal was in demand, as it consisted of no less than 4 ft. of cannel resting on about 1 ft. 6 in. of free coal. Unfortunately, owing to its high position in the sequence, this coal had a somewhat limited distribution, and it has been entirely wrought out.

A third gas coal occurs irregularly in the interval between the previous two. In places it consists of two feet of cannel, but it passes laterally into a thin free coal.

Two gas coals are also known near Pathhead, on the northern margin of the basin, at horizons below the three already considered. The higher was in one place about 6 ft. thick, and is said to have consisted almost entirely of cannel. This seam was at one time treated at the Pathhead oil-works, but little information has been obtained about it, either as regards extent or quality. It is said to lie a few fathoms below the Creoch Coal, and if so, it contains no cannel in other parts of the basin. The lower seam is at present wrought at Mansfield Colliery, where the section is from 6 in. to 1 ft. of gas coal, resting on 2 ft. 6 in. of free coal. This coal lies 56 fms. below the one last mentioned, and probably quite close to the base of the Coal Measures.

In this account of the Ayrshire cannels much use has been made of Dron's ' Coalfields of Scotland,' which treats the subject rather fully. The writers are also indebted to Mr. H. Shaw Dunn, of Annanhill, Kilmarnock, more particularly for information about the disused oilworks.

### 6. ARGYLLSHIRE COALFIELD.

The small Campbeltown Coalfield contains a compound seam of cannel and common coal at a distance of some 30 fms. above the ' Main Coal ' of the field. The thickness of the cannel portion is irregular, varying from a few inches up to 20 or 25 in. The top portion yields up to 36 gallons of crude oil per ton, and the bottom part 27 gallons. It has been worked to some extent in the past, but is not wrought at present. As the field has not been proved very fully and as the thickness of the cannel is not constant an estimate of reserves is not possible, but the position of the seam may extend over two or three square miles.

---

## CHAPTER II.

## SECONDARY AND TERTIARY COALS AND LIGNITES.

The sporadic occurrences of coal, occasionally of serviceable quality, and of brown coal and lignites, among the Secondary and Tertiary formations of Scotland, though they have no significance on the question of the coal resources of the kingdom, have attracted more attention than their value as fuels deserves. One field only, that of Brora in Sutherlandshire, attains to even a local importance.

The other occurrences are found in districts where extensive areas of peat are close at hand and form an easily accessible and

reliable source of fuel. With the exception of the seam of Brora, the coals are seldom more than a few inches thick and inconstant, while the lignites occur for the most part in association with igneous rocks which have frequently destroyed the original combustible character of the bed.

In the description which follows, the coals and lignites will be taken in order, according to their geological age.

## Secondary Coals.

### LOWER LIAS.

*Sutherlandshire.*—The Lower Lias on the east coast of Sutherlandshire is partly an estuarine deposit. It occupies the coast for about a mile near Dunrobin Castle. Professor Judd[1] describes these beds as consisting of sandstones, shales, and beds of coal, and estimates their thickness as not less than 400 to 500 ft. 'Unfortunately these strata are very imperfectly exposed, for under ordinary circumstances only the harder beds appear as reefs upon the shore: when, however, the beach is temporarily scoured away by heavy storms, the bassets of the softer strata of clay and coal are sometimes exposed. It was thus that a bed of coal was exposed to the E.N.E. of Dunrobin Pier, which led in the year 1770 to a boring being undertaken in the Summerhouse Park adjoining. The only record of this boring which remains states that two thin seams of coal were proved, but not deemed worth working.'

Murchison[2] also was acquainted with the journals of this bore. There is no recent record of the coal beds having been seen exposed on the shore, and neither H. B. Woodward, who mapped the district for the Geological Survey, nor Dr. G. W. Lee, who has recently visited the locality, have seen any outcrops of coal in the beach at this place.

### UPPER LIAS.

*Skye.*—In Scotland, jet has never been obtained in workable quantities, and the deposits are merely of scientific interest. Thin streaks of jet were found by Mr. D. Tait, of H.M. Geological Survey, on the east coast of Skye, near Holm, north of Portree. The shales in which it occurs are proved by their fossil contents to be on the same horizon as the Yorkshire Jet Rock, but the fragments obtained were not more than three-eighths of an inch in thickness, and consequently were of no value. Some of the pieces were over 6 in. long, but no large lumps have been found, and the quantity available is certainly very small.

---

[1] 'The Secondary Rocks of Scotland,' *Quart. Journ. Geol. Soc.*, Vol. XXIX, 1873, p. 149.

[2] 'On the Coal-field of Brora in Sutherlandshire, &c.' *Trans. Geol. Soc.*, 2nd Ser., Vol. II, 1829, p. 303.

## GREAT OOLITE.

*Brora.*—In several parts of Scotland the Great Oolite contains beds of coal, but the only seam of economic value is that of Brora in Sutherlandshire. This occurs practically at the top of the Great Oolite and immediately beneath the Oxford Clay, the basal member of which is a calcareous sandstone known as the Roof Bed, with many characteristic Kellaways fossils. Judd gives a long list of its organisms,[1] and considers that in geological position it corresponds with the Kellaways Rock of the Yorkshire coast.

The main seam of coal is on an average about 3 ft. 6 in. thick, and contains in its midst a band of pyrites which detracts greatly from its value. It shows many crushed stems of *Equisetites*. Below the coal Judd states that there are 26 ft. of highly carbonaceous shales, often crowded with plant remains, and alternating with thin bands of crushed shells. This series includes in its upper part several beds of coal varying in thickness from 16 in. downwards; but these do not appear to be so constant as the main seam.

H. B. Woodward,[2] who surveyed the Brora district for the Geological Survey, states that 'another seam, called the Parrot Coal occurs below the Main Coal, and has been found in places to have a thickness of 6 ft. It is a fissile shaly coal of inferior quality.'

Dr. G. W. Lee, who has recently visited the colliery and had an opportunity of examining the section in the main shaft, supplies the following particulars: 'The Brora Coal is from 3 ft. to 3 ft. 6 in. in thickness. Its immediate roof is soft sandstone, 2 ft., which underlies hard shelly calcareous sandstone, 3 ft. thick, of Kellaways age. The coal is black, lustrous, and brittle, breaking into small fragments. It contains a high percentage of disseminated pyrites besides a lenticular band of solid pyrites towards the middle of the seam. The ash content is also very high, a large bulk being left when burnt. Spontaneous combustion, generally starting from the "Parrot" pavement, is of frequent occurrence, both in the mine and in the waste heap. The water from the working galleries is so acid that special arrangements had to be made to drain it directly into the sea, as when drained into the river it killed the fishes. Pipes and other metallic objects deteriorate rapidly under the action of this water.

'The pavement of the coal consists of a "parrot" 3 to 5 in. thick, with an intensely sulphurous layer at its base. This "parrot" rests on a bituminous shale, which is removed to the depth of 2 ft. to make room for the working of the coal. This shale contains many lumps of pyrites. Its thickness in the old

[1] *Op. cit.*

[2] 'Final Report of the Royal Commission on Coal Supplies,' Part VII, 1905, p. 6.

boring record is given as 6 ft. H. B. Woodward (*vide sup.*) mentions a six-foot "parrot" coal as occurring below the Main Coal. The local nomenclature in use at the time of Woodward's survey may have been different from the present one which reserves the term "parrot" for the actual thin "parrot" immediately under the coal, "shale" being the name given to the bituminous shale into which the "parrot" grades downwards.

'Tests of the "parrot" coal gave 32 galls. of crude oil per ton[1] of specific gravity 0·924 and setting point 27° C. The "shale" was tested for oil by Mr. D. R. Steuart, of Broxburn Oil Works, and proved to be worthless.'

The objectionable properties of the coal, its sulphurous odour, liability to spontaneous combustion and high percentage of ash, seem to have been prominent from the first. Hugh Miller[2] furnishes some interesting notes on the difficulties which were experienced by those who had undertaken to work the mines: 'The Brora workings were at no time more than barely remunerative; and the fact that they were often opened, to be as often abandoned, shows that they must have occasionally fallen somewhat below even this low line. Latterly, at least, it was rather the deficient quality of the coal that militated against the speculation than any deficiency in the quantity found. It burned freely and threw out a powerful flame; but it was accompanied by a peculiar odour that seemed to tell rather of the vegetable of which it had been originally composed than of the mineral into which it had been converted, and then sunk into a light white ash, which every breath of air sent floating over carpets and furniture. And so, when brought into competition in our northern ports with the coal of the Midlothian and English fields, it failed to take the market. The speculation of Williams was singularly unlucky. He became lessee of the entire field about the year 1764, and wrought it for nearly five years. There occurs near the centre of the main seam a band of pyritiferous concretions, which here, as elsewhere, have the quality of taking fire spontaneously when exposed in heaps to air and moisture, and which his miners had not been sufficiently careful in excluding from the coal. A cargo which he had shipped from Portsoy,[3] in Banffshire, took fire in this way, in consequence, it has been said, of the vessel springing a leak; and such was the alarm excited among his customers that they declined dealing with him any longer for a commodity so dangerous. And so, after an ineffectual struggle, he had to relinquish his lease.'

The coal raised at the present time is entirely consumed in the immediate neighbourhood. It is used at a brickworks adjacent

[1] Conacher, H. R. J., 'A Study of Oil Shales and Torbanites' *Trans. Geol. Soc., Glasgow*, Vol. XVI, 1917, p. 188.

[2] 'Sketch Book of Popular Geology,' 1869, p. 253–4.

[3] Murchison, *op. cit.*, p. 324. says this cargo was 'going to Portsoy,' which seems much more probable.

to the mine, and in the Brora Wool Mill, which also supplies Brora with electric light. The inhabitants of the district employ it as domestic fuel. About 30 tons daily is the output of the pit; in 1910 the amount raised was about 6,000 tons. This quantity seems to be just sufficient to meet the local demand. Murchison, in 1827, stated that 70,000 tons had been extracted since the year 1814, that is to say, from 5,000 to 6,000 tons a year.

The history of mining this coal dates back to the year 1598, when Jane, Countess of Sutherland, opened the first pit. In 1614, her son John, fifth Earl of Sutherland, re-opened the works. In the early part of the seventeenth century the Earls of Sutherland sank four or five new pits, in one of which 15 men lost their lives by the falling in of the roof. About the year 1764 the working of the coal was undertaken by John Williams, the author of a well-known book on the 'History of the Mineral Kingdom,' but his venture came to a close five years later. These early operations were carried out on the outcrop of the Great Oolite and Kellaways Rock, on the south side of the River Brora and quite near the shore. The sites of many of the old pits are still visible; those first sunk were very shallow and met the coal at a depth of only a few yards. In the pits which Williams worked, the depth to the coal seam was 30 to 40 yds. Salt pans were erected on the shore near the pits, and the coal was used to evaporate the salt water.

A pit was also sunk at Strathsteven; 2 miles south-west of Brora, through the Kellaways Rock to the coal seam, but this part of the coal seam is traversed by a large fault, which runs nearly parallel to the shore and cuts out the coals in a short distance. It is stated that this working was begun in 1872.

About the year 1810 operations were started on the north bank of the Brora River, and a shaft was sunk to reach the coal at a depth of 83 yards. This is the pit which is now working. Another pit, now disused, is marked on the Ordnance Survey maps on the south side of the river about 600 yds. west-south-west of the present pit. Coal workings extend underground between these two shafts and also in the direction of the village of Brora.

A considerable number of borings have been made at various times to prove the depth and thickness of the coal seams. Several of these have been printed in Murchison's and Judd's accounts of the geology of the coalfield. They show that there is a considerable variation in the thickness of the coal seam and the carbonaceous rocks with which it is associated. The average thickness of the coal, as stated above, is about 3 ft. or 3 ft. 6 in. A bore put down in 1770, in Inverbrora Links, gives the section as :—

| | Ft. | In. |
|---|---|---|
| Coal, with a little black stone | 3 | 6 |
| Coal, parrot | 0 | 3 |
| Black Coal or coaly bass | 7 | 0 |

A boring at Faskally, on the Water of Brora, in 1811 proved :—

| | Ft. | In. |
|---|---|---|
| Hard coking coal | 3 | 2 |
| Black clunch | 2 | 0 |
| Hard splint coal | 1 | 4 |
| Black burning shale, like cannel coal | 6 | 7 |

At Strathsteven the coal was 2 ft. 6 in. thick ' with a band of pyrites in its midst,' and rested on 5 to 6 ft. of dark bituminous clay.

The principal unworked area of the coalfield lies to the north of the Brora River. The dip of the rocks is gentle to the north and north-west, and the coal may be at no great depth. A great fault runs nearly parallel to the shore, bringing down the Secondary rocks against Old Red Sandstone strata, granite, and gneiss, and there may be other faults traversing the Jurassic rocks. As much of the ground is covered with Drift and there are no bores in the undeveloped part of the field, it is not easy to form an estimate of the unworked coal resources still available. Woodward[1] states that the area in which coal has been worked is about 30 acres, and from ancient pits and workings near the coast within an undefined area of some 50 acres. There is considerable uncertainty in defining the limits of the coalfield and in allowing for the effects of faults and other disturbances. It is possible that the coal may extend at a depth of 200 to 300 ft. over an area of 3 or 4 square miles, and it is reasonable to believe that the main coal seam may be worked here and there in tracts the united area of which will be not less than a square mile. Mr. J. S. Dixon[2] adopted Woodward's estimate, though he was of opinion that the area and quantity might considerably exceed the figures given in his report, viz., 1,000,000 tons of coal in seams over 2 ft. thick, still available for working. From this it will be seen that the reserves are ample to maintain the present output for two centuries or more.

Heddle[3] gives the following analysis of Brora Shale and Coal :—

| —— | Shale. | Coal. |
|---|---|---|
| | Per cent. | Per cent. |
| Water | 6·247 | 11·494 |
| Gas | 20·338 | 35·077 |
| Residual carbon | 19·72 | 45·183 |
| Ash | 53·895 | 8·246 |
| | 100·200 | 100·000 |

[1] ' Final Report of the Royal Commission on Coal Supplies,' Part VII, 1905, p. 6.

[2] ' Final Report of the Royal Commission on Coal Supplies,' Part VII, 1905, p. 7.

[3] ' Mineralogy of Scotland,' Vol. II, 1901, p. 183.

Another analysis of Brora Coal, quoted from A. Smith (*Trans. S. Staff. Inst. Eng.*, Vol. I., p. 90), is as follows :—

| | Per cent. |
|---|---|
| Fixed carbon | 49·24 |
| Volatile matter | 26·50 |
| Sulphur | 6·40 |
| Moisture | 4·20 |
| Ash | 13·66 |
| | 100·00 |

When coked it yielded 62·90 per cent., the ash contained in the coke amounting to 21·77 per cent.; sulphur, 5·0 per cent.

*Shandwick.*—On the east coast of Ross-shire, 19 miles south of Brora, there is a small patch of Great Oolite rocks which contain a thin coal seam on the same horizon as the Brora Main Coal. These strata were first described by Murchison[1] in 1827; he had his attention directed to them by Sir George Mackenzie. For more complete descriptions we are indebted to Judd, who gives both vertical and horizontal sections of the strata at this locality and a sketch map showing the distribution of the beds. The Jurassic rocks occur in reefs below the cliff, which consists of Middle Old Red Sandstone in conglomeratic and arenaceous beds. The Great Glen fault passes along this shore in a north-eastern direction, bringing down Secondary rocks at more than one locality against Old Red Sandstone, granite, and crystalline schists. Owing to the soft nature of the Secondary rocks, they form no extensive area inland, but occur only in low strips at the margin of the sea. The coal-bearing strata are exposed at a place called Cadh' an Righ, 3 miles south of Shandwick. Judd describes the coal seam as 'a poor carbonaceous band' 4 or 5 in. thick. It rests on a carbonaceous clay 2 ft. thick, and it is interesting to note that above the coal the 'Roof Bed' can be recognised as a bed of calcareous sandstone, one foot thick, having the characteristic fossils of the Kellaways Rock. About 35 ft. of strata are seen beneath the coal seam, dipping south-eastwards and away from the fault which skirts the base of the cliff. On the seaward side the Middle Oolites cover the Great Oolites, but no coal seams are known at this locality except the one above described, which, from its thinness, it is not possible to work.

*Skye.*—In the hills above Loch Cuither, about 5 miles south of Staffin, Mr. D. A. MacCallum describes[2] a seam, 4 in. thick, with grey trap rock above and clay and oil-shale with threads of coal below.

The seam is correlated with the coal of Portree, and is said to be traceable all along the hills from Portree to Loch Cuither.

[1] *Op. cit.*, p. 307.
[2] *Trans. Inst. Min. Eng.*, Vol. LIX, 1920–21, pp. 269–270.

The coal is bituminous, hard, with a glossy lustre, without calcite or pyrites. The analysis given is :—

| | Per cent. |
|---|---|
| Moisture | 16·73 |
| Volatile combustible matter | 42·87 |
| Fixed carbon | 35·79 |
| Ash | 4·61 |
| Sulphur | 0·272 |

### MIDDLE OOLITE.

*Sutherlandshire.*—Workable coals do not occur in this series in any part of Scotland, but some of the beds contain abundance of fossil wood, sometimes preserved as jet. Judd records that in the gorge of the River Brora, at Faskally, there are sandstones, not less than 400 ft. thick, which contain much carbonaceous matter in places, with occasional thin coaly seams, and are evidently of estuarine origin. In the clays beneath this sandstone wood occurs in the form of jet, often in large masses and in considerable abundance.

### UPPER OOLITE.

*Sutherlandshire, Ross-shire.*—The strata of Kimmeridge age at Eathie, south of Cromarty, contain dark shales and clays with abundant fossil wood, which led to the sinking of two shafts in the hope of finding coal, but none was got. No coal seams are known in this series in Scotland. At Navidale, on the coast north of Helmsdale, layers of drifted plant stems, lignite, and jet, up to 3 in. in thickness, were formerly exposed in the shale between two boulder beds on the shore. All the visible fragments were removed by the local fishermen. Oil-shale occurs in these rocks in England, but careful search for a similar deposit on this horizon in Scotland has not resulted in the discovery of any beds of economic value.

### TERTIARY.

*Mull.*—Tertiary lignites occur only in the west of Scotland and are closely associated with the basaltic lava flows and ash beds which form practically the whole of the Tertiary series. Their age has not been satisfactorily established. At one time, on the authority of Edward Forbes and of Heer, they were regarded as Miocene. Subsequently Starkie Gardner, as a result of his studies of the Tertiary leaf beds of Ardtun, in Mull, assigned them to the Eocene, as maintained by Dr. A. C. Seward.

Although they have been worked on a small scale at intervals during more than a hundred years, and are still sometimes worked by the local shepherds and blacksmiths as sources of fuel, these Tertiary lignites have no economic importance. All the known occurrences are so thin, and cover so small an area, that they are very easily exhausted. They do not occur on

any definite horizon and can seldom be traced for more than a very short distance. They form, as a rule, lenticular masses, up to 3 ft. in thickness, and tapering out rapidly or passing into black shale or clay. The lignite has much of the appearance of true coal, as it is black, lustrous, and brittle, and often shows little trace of woody structure or vegetable impressions. It is usually soft, friable, and imperfectly jointed, and lacks the hardness and clean fracture of the Carboniferous coals.

In former years, when the true nature of these beds was not so well understood as it is at present, they sometimes gave rise to extravagant expectations, which were not without the support of scientific travellers, as is evident from Jameson's[1] description of the lignite beds of Béin-anini, in Mull.

'There are several appearances of coal upon this coast, but the most remarkable is that upon the hill called Béin-anini. This hill is composed of horizontal strata of basalt and wacken, which alternate, and rise to the top of the hill like great natural terraces. The coal appears in the bed of a rivulet upon the side of the mountain, is about 3 ft. thick and is immediately covered by basalt. It is one of the greatest strata of coal that has yet been discovered in the Western Islands, and consequently is worthy of particular attention. Several trials have been made with a view to the working of it; but of a nature so trifling that they can deserve notice only as showing how little the importance of the subject has been understood. Sir David Murray, of Stanhope, so far as we can learn, was the first gentleman who seems to have been aware of its consequence; for, about the beginning of the last century, he purchased this hill solely on account of the coal which it contains. He proposed to open the stratum in a very extensive manner, and to work it until he should be satisfied whether it was practicable to continue it to advantage. This scheme was, unfortunately, frustrated by a failure in his affairs, which made him stop working a short time after he had begun. Since that period the property has come into the possession of Sir James Riddell, of Ardnamurchan, who seemed inclined to continue the work of his predecessor, but the business appears to have been committed to persons who were satisfied with making very superficial and unsatisfactory trials.'

Beinn an Aoinidh is a hill on the south coast of Mull, about 4 miles west of Carsaig. In this district there are several outcrops of coal among the lava flows and intrusive sheets. One of these occurs at Dearg Bhealach, half a mile west of Beinn an Aoinidh. Mr. E. M. Anderson states that the section at this locality is as follows :—

| | In. |
|---|---|
| Lava | — |
| Coal | 2 in. to 6 |
| Carbonaceous shale | 6 |
| Bright coal | 6 |
| Clay | ½ |

[1] Jameson, R., 'Mineralogy of the Scottish Isles,' 1800, Vol. I, p. 221.

| | In. |
|---|---|
| Bright coal | 3 |
| Hard splinty coal | 6 |
| Carbonaceous shale | 6 |
| Igneous rock | — |

making a total thickness of 21 in. of coal.

The seam, he states, is very irregular in thickness, and the section alters from point to point. The exposure is near the summit of a high cliff and is rather inaccessible. Coal is exposed at two or three different places within 50 or 100 yds., but the greatest thickness seen is not more than 2 or 3 ft. It cannot be followed continuously along the valley, but at a point half a mile further north a coal seam was at one time visible in the banks of the small stream, where its presence was known to the shepherds. It is at least 18 in. thick.

About 40 ft. above the coal at Dearg Bhealach there is a thick and well-marked lava flow which is exceptional in being coarsely porphyritic, and a similar lava occurs at about the same distance above the coal crop in the burn. Hence there is a considerable probability that these two coals are the same.

On the east side of the valley, on the north-west slopes of Beinn an Aoinidh, there is a stream marked on the 6-in. maps as Allt a' Ghuaill (Burn of the coal). A seam of coal at least 2 ft. thick is exposed in the bed of the burn, and has long been well known to the inhabitants. The coal here is in a burnt condition, with a dull lustre, and friable. Below it there is an inclined sheet of dolerite perhaps 20 ft. thick, and it is probably this sill that has burnt the coal. The coal at this locality may have been worked on a small scale at some time, but there are no traces of adits.

In a parallel stream, about 200 yds. further south, there is a still better exposure. Here the coal is a considerable distance above the intrusive dolerite, and measures 3 ft. in thickness. It is a bright coal with cuboidal fracture, has a clay roof and a hard carbonaceous shale at base. This is the locality at which the mining operations mentioned by Jameson were carried on, but they were confined to the extraction of a small quantity. About 10 years ago a small party of five or six men extracted a few tons of the coal, and it was tried at the smithy at Pennyghael, but the working was soon discontinued. Apart from the irregular thickness and variable character of the coal, the difficulty of transport makes it practically impossible to work it to advantage.

At Carsaig, on the south side of the island of Mull, there is a bed of lignite which has been described by several geologists. Sir Archibald Geikie[1] refers to it in the following terms :—

'At different levels in the volcanic series of Mull, beds of lignite and even true coal are observable. These seem to be always mere lenticular patches, only a few square yards in extent. The best example I have met with lies among the basalts near Carsaig. It is in part a black glossy coal, and partly dull and

[1] 'Ancient Volcanoes of Great Britain,' Vol. II, 1897, p. 213.

shaly. Some years ago it was between 2 and 3 ft. thick, but now, owing to its having been dug away by the shepherds, only some 6 or 8 in. are to be seen. It lies between two basalt-flows, and rapidly disappears on either side.'

This coal seam is visible on the east side of Carsaig Bay, on the east side of an important fault which brings the Tertiary lavas and ash beds down against Jurassic and Cretaceous strata. The locality is about half a mile east-south-east of Innimore Lodge, at an elevation of about 70 ft. above the sea. The cliff is 100 ft. or more in height, and rises sharply to the east of the exposure. It consists principally of basaltic lavas and intrusive sheets with intercalated beds of volcanic ash. The coal appears immediately east of the fault and is about 18 in. thick. The coal is dirty, soft and friable, and brownish-black in colour. Above and below it are several feet of sandy shales. An intrusion of columnar basalt cuts across the seam obliquely. The extent of the exposure is not more than 40 yds., but about 200 yds. further east the coal is again seen in a very irregular state and much broken by intrusions. Half a mile east of the fault there is a grey shale with plant remains at An Dunan, but no coal is visible at this place. Although small quantities of coal have been taken from this outcrop at various times during a period extending over more than 100 years,[1] it is not known that any attempt has been made to work it recently. In 1845 boring was being prosecuted at Carsaig in search for coal.[2]

Dr. Clough[3] has given some notes on Tertiary coals in the Carsaig and Bunessan districts. He states that the shepherd at Shiaba, 4 miles south-east of Bunessan, sometimes worked a coal for home use at Eas Dubh, half a mile east of Shiaba. 'This coal has for the most part a dull brown colour and seems of a "parroty" nature. In one place it is 2 ft. thick, but diminishes to 6 in. within a few yards. It dips steeply east, and cannot be traced far.'

The leaf-beds of Ardtun, north of Bunessan, were first brought into prominent notice by the late Duke of Argyll.[4] These beds are not really lignites but shales with well-preserved leaf impressions. A fuller description of their contents was subsequently given by Starkie Gardner,[5] and as they are the most important Tertiary fossiliferous strata in the west of Scotland, they have deservedly attracted much attention.

In the same district there are also coal seams of which some particulars are given in the scientific papers above mentioned.

---

[1] J. Macculloch, 'Western Islands of Scotland,' Vol. I, 1819, p. 565.

[2] 'New Statistical Account of Scotland,' Vol. VII, Argyllshire, 1845, p. 304.

[3] 'Summary of Progress for 1910' (*Mem. Geol. Surv.*), 1911, p. 40.

[4] 'On Tertiary Leaf-beds in the Isle of Mull,' *Quart. Journ. Geol. Soc.*, Vol. VII, 1851, p. 89.

[5] 'On the Leaf-beds and Gravels of Ardtun, Carsaig, &c., in Mull,' *Quart. Journ. Geol. Soc.*, Vol. XLIII, 1887. p. 270.

One of these, at Gowanbrae, a little north of Bunessan, was opened up many years ago by means of shallow pits; we believe this was done on behalf of the Duke of Argyll, who was the proprietor. The trials must have proved unsatisfactory, as no attempt was made to carry the work further. Around the pits, which are still visible, pieces of dark shale with fragments of wood and traces of leaves are to be found, but no exposure of the coal can now be seen. Another coal seam, which also is, according to Dr. Clough, of no prospective value, occurs east-south-east of Torr Mor, on the south shore of Loch Scridain, about 5 miles east of Ardtun. Its position is indicated on the map which appears with the Duke of Argyll's paper on the Ardtun leaf-beds.

In other parts of Mull beds of lignite are known to occur, intercalated among the lava flows, but none of them has any economic importance. One of these recorded by Starkie Gardner[1] is in the Wilderness north of Burgh Head, Loch Scridain, about 250 ft. above sea level. Another is stated to occur in Gribun, on the south side of Loch na Keal.[2]

The tradition of coal at Loch Aline, Morvern, Argyllshire, refers to a lenticular pocket found at the base of the Tertiary series above Ardtornish Towers. Some 2 tons of impure lignite were extracted from this pocket in the seventies of the last century, but search along the outcrop failed to show any further supply.

*Skye.*—The Tertiary lignites of Skye appear from an economic standpoint to be even less important than those of Mull. By far the best account of them is that given by Macculloch[3] in 1819, at a time when they attracted considerably more attention than they have done of recent years:—

'There is but little to be said respecting the coal of Skye, the position of this mineral being commonly as obscure as its quantity is insignificant. Although a subject of much anxiety to the inhabitants and proprietors, it presents but little to reward the toil of a geologist.

'It is found in two distinct positions, in the one case included in trap, in the other interposed among the upper strata already described.

'The first example to be mentioned partakes in some measure of both these positions, the stratum, which is little more than an inch in breadth, being interposed between common shale and siliceous schist and the whole included in trap. It is to be seen between Loch Sligachan and Conurdan.

'At Talisker a short and thin bed of coal accompanied by bituminous wood is found entangled in the trap rock, but so high in the cliff as to be scarcely within the reach of examination. On the farm of Scoribreck, near Portree, it is also found in several

[1] *Op. cit.*, p. 284.

[2] 'New Statistical Account of Scotland,' Vol. VII, Argyllshire 1845, p. 304.

[3] *Op. cit.*, p. 360.

places among the trap, but always in an insignificant quantity, and scarcely amenable to investigation. Larger masses similar to these occur on the shore at Camastianavaig and in Portree Harbour. In these places it lies in irregular nests in the surrounding rock, varying from a quarter of an inch to a foot in thickness. The mass in Portree Harbour has been wrought and abandoned, after furnishing, as it is reported, 500 or 600 tons. It is said to have reposed on shale, while above, it was in contact with the trap, and to have extended from one foot to three in thickness; but it is now invisible, having been overwhelmed by the fall of the superincumbent rocks. It is still, however, apparent that it must have been cut off on both sides by the same mass of trap by which it was covered. The fragments still existing about the spot present much carbonised wood and pyrites, and are accompanied by pieces of bituminous shale.

'Similar, but more limited appearances of coal, are found near the head of Loch Grisornish, near Dunvegan, in Strathaird, and in other places; but they are so insignificant in a topographic view and so uninteresting in an economical one, that I shall forbear to point out more of them . . .

'The appearances of coal among the stratified rocks are still more trifling, while in most cases they are either overwhelmed or cut off by trap, so that they cannot be pursued for any continuous space. Their thickness rarely extends to a few inches, and they are found alternating dispersedly with shale and sandstone over different parts of the surface of Trotternish.

'Among other places where they are visible, I may name Loch Uig, and the waters of Leolt, Grocheard and Grimset . . .'

In the 'New Statistical Account of Scotland'[1] it is stated that 'about 40 years ago, Lord Macdonald, principal heritor of the parish, attempted to work a coal mine, in two different parts of the parish (Portree). He was at the expense of getting a number of hands from the low country, experienced colliers; but, after repeated trials, from the smallness of the vein, and the great difficulty of working it, embedded as it was under high rocks and below high-water mark, it was ultimately discovered that the quantity of coal procured would pay but a small proportion of the expense incurred. The work was then abandoned and has never since been resumed.'

Dr. G. W. Lee, who has recently examined the locality, reports that the day-level is now inaccessible, the roof having caved in, and no samples can be obtained.

In the Geological Survey Memoir on Glenelg, &c. (p. 172), Dr. Harker remarks that 'the local traditions of coal in the country west of the Broadford strath, both in the Oolitic series and in the Basaltic group, can only refer to small inconstant seams, quickly exhausted by the residents.' He also found that the Tertiary coal, though usually impure, is sometimes of good quality ('Tertiary Igneous Rocks of Skye,' *Mem. Geol. Surv.*,

[1] 'New Statistical Account of Scotland,' Vol. XIV, 1845, p. 221.

p. 10). At An Ceannaich, south of Dunvegan Head, Sir A. Geikie has remarked a seam of coal, about a foot thick, of remarkable purity. It is described as glossy, hard, and cubical, including layers that break like jet (*Quart. Journ. Geol. Soc.*, Vol. LII, 1896, p. 342).

Heddle ('Mineralogy of Scotland,' Vol. II, 1901, p. 183), gives the following analysis of lignite from Vaternish, Skye :—

| | Per cent. |
|---|---|
| Water | 10·00 |
| Gas | 36·40 |
| Residual carbon | 50·16 |
| Ash | 3·44 |
| | 100·00 |

*Canna.*—In this island also[1] there are thin beds of black lignite among the stratified agglomerates and volcanic ashes between the Tertiary lava flows, but none of them seems to have been worked as a source of fuel.

## CHAPTER III.

## OIL-SHALES (MINOR OCCURRENCES).

### *Introduction.*

The centre of the oil industry of Scotland was always that part of West Lothian which lies between the Bathgate Hills and the River Almond and Linhouse Water, but at one time or another oil works have been established at Aberdeen, Edinburgh, Kilrenny in Fife, Lanark, Paisley, and Kilmarnock. Most of these works were either treating cannels or other coals of local origin, or boghead and oil-shale derived from Linlithgowshire. At Burntisland, on the north side of the Firth of Forth, an important oil works, now dismantled, retorted the shale mined in the oil-shale field at Binnend. To the south-east of Edinburgh the Clippens Oil Company at Straiton for many years carried on the distillation of the oil-shale mined in that neighbourhood. All these enterprises, as already stated, are now extinct, and accordingly when, in 1906, the Geological Survey arranged for the preparation of a memoir on the oil-shale fields of Scotland, the geological portion of that work was restricted to descriptions of the shale fields of West Lothian, Midlothian, and Burntisland and Inverkeithing in Fifeshire. That memoir, of which a second edition was published in 1912, contains full particulars of the deposits which are now being worked, and which alone, in the economic conditions that existed before the war, were considered

[1] Sir A. Geikie, 'Ancient Volcanoes of Great Britain,' Vol. II, 1897, p. 223.

worth mining. There are, however, in Scotland some areas in which oil-shale is known to occur, not only in the Lower Carboniferous beds which have received the name of the Oil-shale Group, but also at other horizons in the Carboniferous and even in the Secondary rocks. These are mostly thinner than the worked deposits of shale, and are in many cases of inferior quality. In the following pages a short account is given of oil-shales in Scotland outside the Lothians and the south of Fife.

The shales which are at present used in Scotland for the production of paraffin oils have certain fairly well-marked characters. They are black or sometimes dark brown in colour, with a dark brown to black streak, and generally very fine-grained, showing even under the microscope few gritty particles of quartz or other minerals. Most of them have a distinct lamination parallel to the bedding, but the best qualities at any rate are not, as a rule, fissile. Oil-shales are frequently so tough as to resemble black wood, and on the shore of the Firth of Forth large rounded blocks may be seen which have been rolled to and fro by the waves without splitting up, as ordinary shales would certainly have done under the circumstances. This property of toughness also has led to the use of oil-shale, where it can be got in large thin pieces, to form the covers of drains. It is also very resistant to the weather, and nearly indestructible by frost or wet. Two varieties of oil-shales are commonly recognized by the miners, viz., plain shale, which has a flattish lamination, and curly shale, in which the lamination is curved or crumpled, with sometimes lustrous polished planes of separation, and slickensided surfaces. The origin of the curly variety of oil-shale is not clearly determined, though many believe that it may be due to movement in the seam. Some shale beds show this peculiarity over a considerable area. At Broxburn, for example, there is a band of curly shale 5 ft. above the Broxburn Shale. It is not specially rich as a source of oil.

The shales at present mined contain organic matter yielding at least 19 galls. of crude oil per ton of shale, and 20 to 40 lbs. of sulphate of ammonia. A rich oil-shale gives 60 or 70 galls. of crude oil per ton, but not much of this quality is now obtainable. Torbanehill mineral or boghead yielded from 90 to 130 galls. of oil per ton. Some of the poorer shales are more valuable under ordinary conditions for their ammonia than for the oil, and might be described as ammonia shales, giving oil as a by-product; but this entirely depends on the relative amounts and values of the products under fluctuating market conditions. It may be remarked, however, that those shales which yield much oil are not always, and in fact are not usually those which yield most ammonia; but the relative yields depend to some extent on the temperatures and conditions under which the distillation is conducted.

The inorganic matter or ash contained in a series of representative oil-shales analysed by Mr. J. B. Robertson[1] varied from 82 per cent. to 60 per cent.; in the Torbanehill boghead the ash amounted to only 17·66 per cent. After distillation the ash or spent shale is thrown out upon the waste heaps; it has a brick-red colour from the oxidation of the iron compounds in the rock, and, unlike the fresh shale, it is perfectly fissile, as the thin laminæ of clay readily separate. Silicate of alumina is the principal ingredient of the ash. Mr. Robertson's investigation of the chemistry of the oil-shales showed that the organic matter they contain is not very dissimilar to that of coals, the principal distinguishing feature being that oil-shales contain more hydrogen in proportion to their carbon; in this respect they approach closely to the cannel coals, as might have been expected from what is known regarding the volatile products obtained by distillation of cannels and oil-shales. Experiments made with Scotch coals proved that they give usually from 20 to 30 galls. of crude oil per ton, and the oil has a higher specific gravity than the crude shale-oil, probably because of the presence of a greater proportion of compounds of the benzene-ring type in the coal-oil, while the shale-oil contains more paraffin compounds.[2]

Microscopic sections of the Lothian oil-shales show that they are finely laminated clay rocks rich in organic matter. Very minute grains of quartz are often present, but not in great numbers, and small calcareous fragments, probably of ostracod shells, are not infrequent. The organic matter consists of: (*a*) pieces of woody tissue, usually small and macerated; they are dark brown in colour and the cellular structure is sometimes preserved; (*b*) spores, both large and small, with the spore-wall sometimes entire and sometimes ruptured; (*c*) 'yellow bodies'; (*d*) a brown homogeneous, structureless material, that looks like a humic decomposition product of vegetable matter. Some oil-shales are so richly impregnated with this humic or sapropelic material that in thin section they resemble old polished mahogany, having a dark reddish-brown colour, while the lamination of the shale recalls the grained structure of wood.

The nature of the yellow bodies has given rise to much controversy, and is still unsettled. First brought into notice during the lawsuit regarding the Torbanehill mineral, of which they compose nearly the whole mass, they are found in all sections of oil-shales in varying abundance and perfection. They are not confined to oil-shales, however, but appear also in cannels and even in ordinary coals, though in the last-named they are subsidiary ingredients. The yellow bodies are of microscopic size (from ·05 to ·1 mm. in diameter) and not visible with the

[1] A Chemical Examination of the Organic Matter in Oil-shales, by John B. Robertson. *Proc. Roy. Soc. Edin.*, Vol. XXXIV, 1914, pp. 190–201.

[2] 'Oil-Shales of the Lothians' (*Mem. Geol. Surv.*), 2nd edition, 1912, p. 166.

naked eye. In oil-shales they are usually flattened parallel to the lamination of the rock, so that they are discoid in shape. Internal structure is seldom to be observed in them, and if they have an external wall it is thin and is seldom obvious under the microscope. In 'bogheads' the yellow bodies are larger and have a rounded or sometimes slightly lobate outline, with traces of a reticulate internal structure.

It has been suggested that the yellow bodies are due to the impregnation of a shale with inspissated petroleum, but we are not aware of any evidence that makes it likely that such a process would have given rise to bodies possessing these characters. The larger bodies of the bogheads have been described by Bertrand and others as fossil plants of lowly organisation, and different species have been figured as *Pila*, *Reinschia*, &c. Whether these are the same as the smaller yellow bodies of the oil-shales is not certain. It is difficult to believe that the delicate tissues of plants which had no woody skeleton would be satisfactorily preserved in such conditions. The general uniformity in size and the rounded shape of these bodies are certainly in favour of their organic origin; if they were mere debris of the larger plants or secondary concretionary masses they would probably have been much more irregular in these respects. It has also been suggested by Schuster[1] that the yellow bodies are concretions of resin set free by the maceration of woody tissue in the water of the Carboniferous lagoons.

The oil-shales were deposited in shallow pools of water. There are no underclays beneath them, but they often overlie thin shale beds containing marine shells, indicating a temporary incursion of the sea through more rapid subsidence. They are not associated with coals in the district under consideration, and do not pass laterally into coals or into ironstones, but in these respects they differ from the shales of the Upper Carboniferous. On the other hand, they are often observed to pass laterally into carbonaceous shales or blaes which are valueless as sources of oil. It is clear that the oil is derived by destructive distillation of the organic matter of the shales, the so-called 'kerogen,' and that this organic matter is of vegetable origin, and is different in several respects from the vegetable matter which has formed the bulk of the ordinary coals and coaly shales.

## Oil-Shales in the Carboniferous Rocks.

*Midlothian.*—For particulars of the shales now worked in the Lothians reference must be made to the Memoir on the 'Oil-shales of the Lothians' (2nd Ed., 1912). That memoir, however, does not deal with the basal members of the Oil-shale Group cropping out near Granton, since they are mostly of inferior quality and have more a scientific than economic interest.

[1] 'Neues Jahrbuch für Mineralogie,' 1912, Vol. II, p. 40; Conacher, H.R.J., *Trans. Geol. Soc., Glasgow*, Vol. XVI, 1917, p. 164.

*Section of Carboniferous Strata—Mid and West Lothian.*

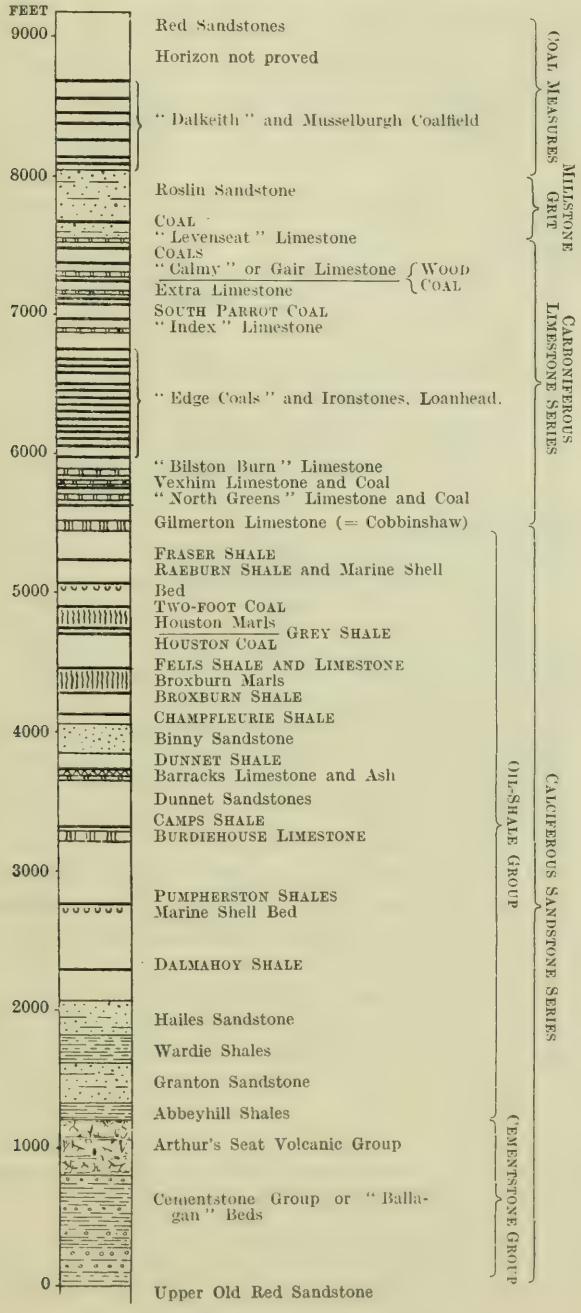



Fig. 3.—General Vertical Section of the Carboniferous Strata of Mid and West Lothian.

The following account of the basal members of the group is taken from the 'Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 2nd Ed., p. 76–79, 1910.

These oil-shales occur in the Wardie Shales and are best exposed in the syncline on the shore between Trinity and the General's Rock, 330 yds. west of Granton Harbour. The following vertical section gives the position of the oil-shales in this sequence :—

| | Ft. | In. |
|---|---|---|
| Sandstones and grey papery shales | 60 | 0 |
| Oil-shale | 6 | 0 |
| Black and grey shale | 20 | 0 |
| Curly oil-shale (analysis No. 3 below) | 6 | 0 |
| Blue and black shale with thin bands of volcanic ash | 6 | 0 |
| Oil-shale | 2 | 0 |
| Blue and black shale | 8 | 0 |
| Sandstone with *Stigmaria* | 20 | 0 |
| Blue and grey papery shale | 35 | 0 |
| Oil-shale with entomostracan bands | 6 | 0 |
| Curly oil-shale (analysis No. 2 below) | 6 | 0 |
| Poor shale | 6 | 0 |
| Blue oil-shale | 4 | 0 |
| Shale with entomostracan bands | 4 | 0 |
| Sandstone and grey papery shale | 12 | 0 |
| Grey papery shale and thin ironstone bands | 28 | 0 |
| Oil-shale (analysis No. 1 below) | 2 | 0 |
| Sandstone | 6 | 0 |
| Nodular fireclay and thin coal | 25 | 0 |
| White sandstone | 20 | 0 |
| Black shale with plants | 55 | 0 |
| Black shale with fish, coprolite, and balls | 70 | 0 |
| Thin grey band of volcanic ash | 2 to 4 | 0 |
| Black shale | 25 | 0 |
| Hard yellowish sandstone | 12 | 0 |
| Grey papery shales | — | |
| Coal, formerly worked at Wardie | — | |

Beneath the coal come about 200 ft. of black shales with black sandstones and dark limy beds, and near the base an oil-shale (analysis No. 4 below) not far above the top of the Granton Sandstone at the General's Rock.

Analyses of the weathered shale give for No. 1, 7·68 galls. of crude oil and 22·97 lbs. of sulphate of ammonia per ton of shale; No. 2, 3·20 galls. of crude oil with 20·80 lbs. of sulphate of ammonia; No. 3, 16·00 galls. of crude oil with 16·00 lbs. of sulphate of ammonia; No. 4, 13·44 galls. of crude oil with 21·92 lbs. of sulphate of ammonia. As a rule, it is considered that these laboratory determinations of ammonia should be doubled to give approximately a works result.

Around the Midlothian Coalfield, which forms an elongated syncline to the east and south-east of Edinburgh, the Lower Carboniferous rocks outcrop in a north and south belt, which is narrow on the west side, but on the east covers a wide area, extending along the shore from Dunbar to Port Seton and south to Carlops and Lamancha.

On the west side oil-shales in these beds were for a long time worked at Straiton, 4 miles south-east of Edinburgh. At Carlops also, 9 miles south-east of Edinburgh, an oil-shale field has been proved to exist and its structure ascertained by an extensive system of bores, but no attempt has been made to work it.

All down the western edge of the coalfield the strata are inclined at high angles (40°–80°), but at Carlops the beds flatten out, though the oil-shales measures are here in a remarkably attenuated form.[1]

On the east side of the basin, oil-shales are known to occur, but not in workable thickness or condition. Natural exposures are few and scattered, and few borings have been put down in search of minerals or of water.

Recently the presence of this group and of an oil-shale has been proved in the experimental boring for oil at D'Arcy, $2\frac{1}{2}$ miles south-east of Dalkeith (p. 61). The boring commences a few feet below the outcrop of the D'Arcy Limestone (No. 2, or Skateraw Limestone) and at a depth of 118 fms. there occurs an oil-shale appoximately 15 ft. thick and resting on a sandstone that gives off a large quantity of gas. There is little doubt that it represents one of the high bands of the Oil-Shale Group on the west side of the basin. The commercial value, however, cannot be estimated from samples obtained by the method of drilling, which gives only small chips.

*Margins of the Central Coalfield.*—Of the shale-fields which are at present worked, the Tarbrax field is the furthest south-west, and north of that the boundary of the workable shale district may be taken as corresponding to the eastern edge of the lavas of the Bathgate Hills. The oil-shale measures may extend westwards beneath the Carboniferous Limestone, Millstone Grit, and Coal Measures of the Central Coalfield, but they have nowhere been proved by bores in that area. Along the southern edge of the Central Coalfield the Calciferous Sandstone rises to the surface and covers a fairly large extent of ground. Of recent years much of this ground has been re-surveyed in connection with the revision of the geological maps of the Central Coalfield, now in course of publication; but the new information obtained in this way has not led to the expectation that important reserves of oil-shale are contained in the Calciferous Sandstone rocks of that district to the south-west of Tarbrax.

If we accept the Main Limestone of Carluke and Cobbinshaw as the base of the Carboniferous Limestone, some of the highest recognized oil-shales should occur within a hundred fathoms of that position. Between Carnwath, Auchengray, and Tarbrax there are no known outcrops of oil-shale and only a few bore records from that ground have been collected. A bore at

---

[1] 'The Oil-Shales of the Lothians' (*Mem. Geol. Surv.*), 2nd ed., 1912, pp. 87–88.

Browshot, Braehead, about 3 miles north-west of Carnwath, passed through the Main Limestone at 10 fms., and thereafter through various beds of sandstone and blaes to a depth of nearly a hundred fathoms, without meeting with any recognizable oil-shale. Another bore near Muirhall, a mile south of Auchengray, passed through at least one band of 'shaly blaes' but no good oil-shale; and other bores further south record 'blaes' or shale with thin bands of oil-shale. To the north of this, on the west side of Cobbinshaw Reservoir, boring operations in search of shale are being carried on.

On the west side of the valley of the Clyde the Calciferous Sandstone has only a restricted development. During the early part of the Carboniferous period this country was the scene of prolonged volcanic activity, and lavas and ashes accumulated to a great thickness. The lowest sedimentary beds of the Carboniferous are usually red, ashy mudstones, composed of debris of the underlying volcanic rocks, which seem to have formed a fairly extensive land surface, which gradually sank beneath the Carboniferous sea. Over these ashy mudstones there is sometimes a variable thickness of Calciferous Sandstone strata; at other places the Carboniferous Limestone rests almost directly on the lavas, with only a thin intervening representative of the ashy mudstones; this is the case, for example, in the East Kilbride district.[1]

Further south, near Strathaven, Calciferous Sandstone strata are exposed on the banks of the Avon Water, near Cot Castle, and among these Mr. Carruthers has recognized two oil-shales, which he correlates with the Raeburn and Fraser Shales of the Lothians oil-shale fields.[2]

The following particulars are extracted from 'The Economic Geology of the Central Coalfield of Scotland, Area IX' (*Mem. Geol. Surv.*), 1921, p. 18.

About 400 ft. of Calciferous Sandstone strata are known in the Strathaven district to intervene between the ashy mudstones and the base of the Carboniferous limestone. The lowest distinctive horizon is that of the Walkerdyke coals, which are seen on Hole Burn, from 150 to 250 yds. north of Laigh Walkerdyke steading. The Raeburn Shale is seen at the top of the south bank of the Hole Burn, 200 yds. below Laigh Netherfielddyke. Although too thin to be of much economic importance, it is an oil-shale of the true Lothian type, unlike most of the other so-called 'shales' in Lanarkshire, which are more of the nature of 'parroty blaes.' The marine band which underlies this oil-shale may be called the Raeburn Shell Bed. It is the equivalent of the 'Mungle Shell Bed' of the Oil-shale Memoir

[1] 'Economic Geology of the Central Coalfield of Scotland' Area VIII, East Kilbride and Quarter. (*Mem. Geol. Surv.*), 1917, p. 9.

[2] 'Summary of Progress' for 1912 (*Mem. Geol. Surv.*), p. 60. R. G. Carruthers, 'The Carboniferous Sediments around Strathaven.' *Trans. Geol. Soc., Glasgow*, Vol. XV, pt. II., 1912–15, p. 151.

(2nd Ed.); it is fairly prolific in small *Productus*, *Lingula*, &c., while the typical Oil-shale fern, *Telangium affine*, occurs abundantly in the blaes below.

At Marr's Pool in the Hole Burn, the calcined top of the Netherfield Coal is seen crossing the burn. Above this there is an excellent exposure of the Netherfield Limestone. This horizon, about 18 ft. thick, shows a few inches of limestone, in bands, but for the most part is a dark blaes, with a great profusion and variety of small marine organisms. At the top of this blaes there is a 3-in. rib of limy ironstone, in which the fossils are particularly well preserved. The whole position may be correlated with the Shell-bed below the Fraser Shale of the Lothian Shale Fields.

Resting on the Netherfield Limestone, a 4-ft. band of shaly blaes, without fossils, can be observed on the south bank of the stream. This represents the Fraser Oil-shale of the Lothians, and although it is here of very poor quality as an oil-producer, the characteristic platy weathering of this type of sediment is very noticeable, when compared with the usual type of blaes below.

The Castlecary Limestone is often overlain by an oil-shale. In the limestone workings at Levenseat near Fauldhouse the shale was 15 inches thick and was to a small extent distilled for oil in the early days of the oil industry. It yielded 33 gallons of crude oil per ton.

*Berwickshire and Haddingtonshire.*—On the Berwickshire coast, at Cove Harbour, half way between Dunbar and St. Abb's Head, an oil-shale is seen outcropping in the beach below high-water mark for a distance of over 600 yds. This district was revised in the year 1900 by Dr. Clough, and the following notes are mostly taken from his account of the rocks in the memoir on 'The Geology of East Lothian' (*Mem. Geol. Surv.*), pp. 42–50.

The Cove Oil-shale is a foot to 15 in. in thickness and dips at low angles to the eastwards beneath the sea. It is sharply folded in a small anticline and syncline, and consequently the outcrop has an S-shaped form. About 300 yds. to the west there is an important fault which brings lower beds against a series of coals which are correlated with the Scremerston coals of Northumberland. These coals have not been worked to any extent, and nothing is known of the structure or relations of the rocks where they extend seawards. The oil-shale is fine-grained, black, and seems to be of fairly good quality, but it has not been tested for oil. Its thinness debars the possibility of working it.

In the beds beneath the oil-shale, there are two limestones (the Upper and Lower Cove limestones) which were correlated by Mr. Gunn with the Dun and Woodend limestones of Northumberland. These latter have a thick sandstone above them, and beneath them lie the Scremerston coals, approximately in the same position as the Cove Harbour coals. The oil-shale accordingly is on the same horizon as the Doubster Oil-shale of

Northumberland; it is the most northerly representative of that oil-shale, as, in the Dunbar district and the area occupied by the Carboniferous Limestone on the east side of the Midlothian basin, no oil-shale has been observed in this position.[1]

Along the coast towards Dunbar, to the north-west, the Cove Oil-shale re-appears at Bilsdean, as is shown in the colour-printed edition of one-inch Geological Sheet 33; it is about one foot thick and is overlain by pale grey shale with courses of ironstone. Further to the north-west, about Innerwick and Thorntonloch, no oil-shale is known on this horizon; consequently the relation of the Cove Oil-shale to the Longcraig limestones, which are taken as the base of the Carboniferous Limestone Series in this district, is not exactly known, but it seems likely there may be 500 or 600 ft. of strata between them.

At Cheese Bay, which is about 2 miles to the north-east of Gullane (1-in. Geological Sheets 33 & 41), a thin band of oil-shale was discovered by Mr. Macconochie in 1903, and has proved to be very rich in fossil fishes and crustacea. The section as described by Dr. Traquair[2] is as follows :—

| | |
|---|---|
| Hard, ferruginous cementstone - - | 6 in. |
| Shale, partly oil-shale - - - | Several feet. |
| Shale, fine-banded, purplish and grey - | 2 ft. |

The oil-shale is not now well exposed on the shore, as the outcrop has been quarried in search for fossils, but there is probably not more than 2 ft. of black shale, and it has not been tested for oil.

This bed occurs a short distance above the contemporaneous lavas and ash beds that cover so large an area in the neighbourhood of North Berwick and Haddington, and is probably at a low level in the Calciferous Sandstone. The results of Dr. Peach, Dr. Traquair[3] and Dr. Kidston's[4] examination of the fossil crustacea, fishes, and plants in these shales indicate that they are probably on the horizon of the Wardie Shales, which in the neighbourhood of Edinburgh also contain thin bands of poor oil-shale (*see* p. 48).

### Oil-Shales in the Jurassic Rocks.

*Raasay and N.E. Skye.*—In Raasay and N.E. Skye the base of the 'Estuarine Series' (Fuller's Earth and probably Great Oolite) is marked by an oil-shale, 8 to 10 ft. thick, which follows conformably and gradually upon the clay of the Garantiana Zone. This occurrence has been described in 'Nature' for

[1] W. Gunn, 'Notes on the Correlation of the Lower Carboniferous Rocks of England and Scotland' *Geol. Mag.*, 1898, p. 342.

[2] R. H. Traquair, 'Report on Fossil Fishes collected by the Geological Survey of Scotland on the Shore near Gullane, East Lothian' *Trans. Roy. Soc., Edin.*, Vol. XLVI, 1909, p. 103.

[3] *Loc. cit.*

[4] 'Geology of East Lothian' (*Mem. Geol. Surv.*), 2nd ed., 1910, p. 217.

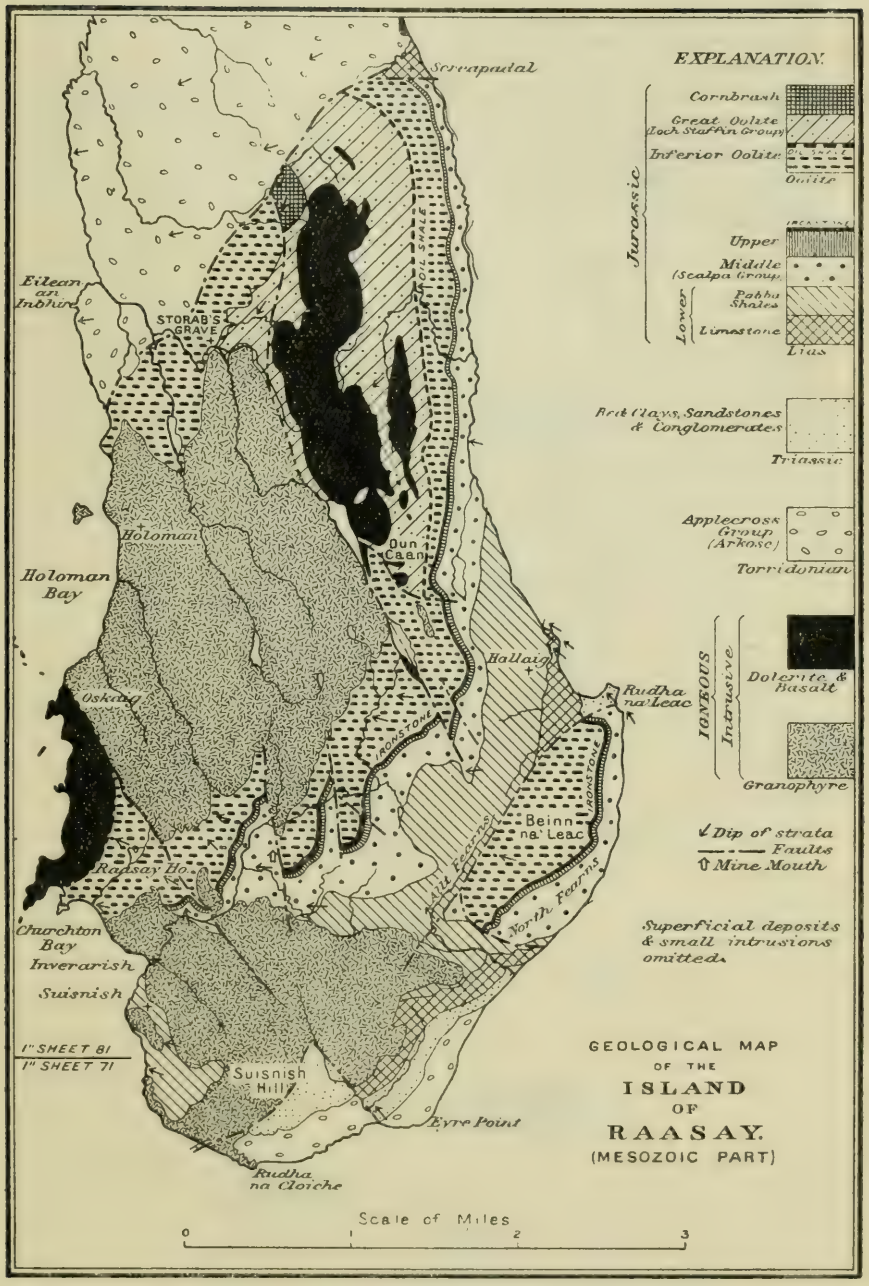



FIG. 4.—Geological Map of the Island of Raasay.

9th October 1913, and in the ' Geological Survey Memoir on the Mesozoic Rocks of Applecross, Raasay, and North-East Skye,' from which the present account is taken.

The outcrop of this shale in Raasay is almost everywhere hidden by talus or by vegetation, but there is a good exposure at the top of the cliff due east of Dun Caan. But even where not actually seen, it can quite easily be recognised from the marked feature it forms between the Inferior Oolite below and the sandstone which comes above.

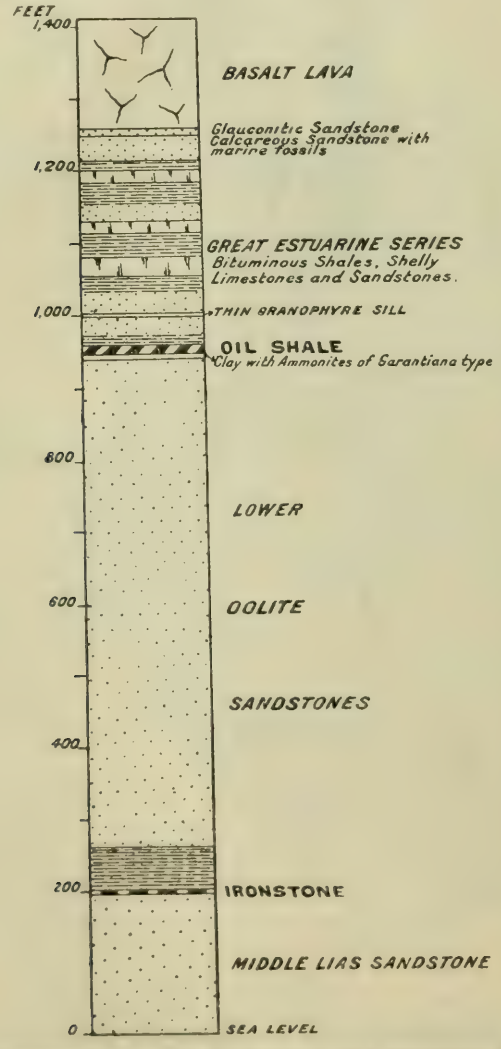



FIG. 5.—Diagrammatic section illustrating the sequence of the Jurassic rocks below Dun Caan, Isle of Raasay.

The shale is a true oil-shale, much like the Carboniferous shale worked for oil in the neighbourhood of Edinburgh, but it

is not likely to possess any economic value under present conditions. Any indication as to its oil contents would require to rest on the analysis of fresh, unaltered shale, obtained some distance from the weathered surface. An analysis of weathered samples kindly undertaken for the Survey by Mr. D. R. Steuart, of the Broxburn Oil-works, gave 12 galls. of crude oil per ton of shale, with 6·2 lbs. of sulphate of ammonia, which is equivalent to at least 12 lbs. in a works retort. That the fresh shale might be expected to yield more than weathered portions seems probable, but to what extent is not known.

The position of the shale on the east of the field in Raasay forms a straight north and south feature readily followed as far as the top of the cliff above Screapadal. On the west side of the field there is an exposure of the shale in the banks of the stream east of Storab's Grave, but quite burnt by the proximity of the great granophyre intrusive sheet. Part of the seam is to be seen in the right bank of the stream N.E. of Storab's Grave, where it also appears to have suffered from the action of the igneous intrusion.

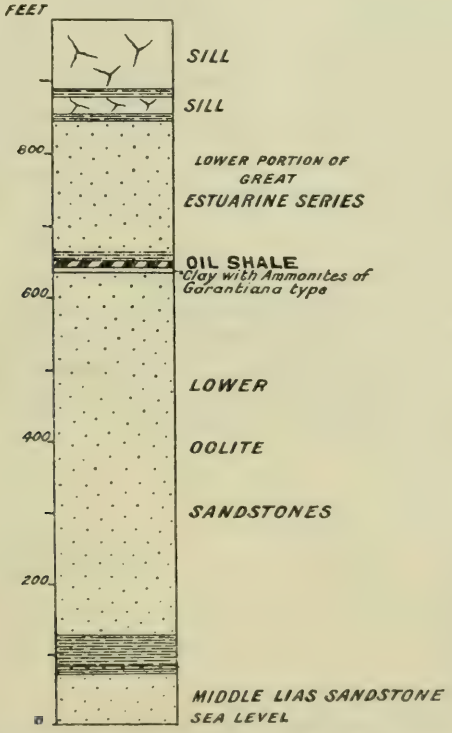



Fig. 6.—Diagrammatic section illustrating the sequence of the Jurassic rocks in the cliff between Holm and Prince Charles's Cave, Isle of Skye.

In N.E. Skye the seam has been traced from Ollach—south of Portree Bay—to Bearreraig, north of Portree Bay. It consists of about 7 ft. of shale proper, capped by some 3 ft. of bituminous

sandy shale. A compound sample from the much-weathered outcrop between Holm and Prince Charles's Cave gave on analysis by Mr. Steuart 12·8 galls. of crude oil per ton, and 7·4 lbs. of sulphate of ammonia. Another analysis, cited by Mr. H. R. J. Conacher[1], showed 17 galls. of crude oil, of specific gravity 1·006, and setting point below 18° C.

At various points, notably south of Prince Charles's Cave and on either side of Camastianavaig, the shale has been subjected to the destructive action of igneous rocks, and has lost all its oil contents. It appears in its unaltered state only north of Prince Charles's Cave and in the cliff N.E. of Ben Tianavaig.

---

## CHAPTER IV.

## MINERAL OIL.

In Scotland, records of the occurrence of mineral oil, and of mineral substances derived from petroleum, are few. Main seepages of oil are limited in all cases to workings in coal and oil-shale belonging to the Carboniferous System; as are other and slight flows in unworked areas of Carboniferous rocks. None are of commercial consequence, but few and unimportant as the seepages are, they undoubtedly have given rise to the opinion that, under suitable conditions, oil in commercial quantities possibly occurs in Scotland.

### Natural Occurrences.

*St. Flanans.*—The most copious oil-flow recorded in Scotland occurred in the years 1903 to 1908, at St. Flanans Pit, in the Twechar district, near Kilsyth. This pit works the Kilsyth Coking Coal at a depth of 88 fms. The section of the strata immediately above and below the coal is :—

| | Ft. | In. |
|---|---|---|
| Irony fakes | 0 | 5 |
| Faky blaes | 2 | 6 |
| Irony fake, hard | 0 | 6 |
| ,, soft | 0 | 6 |
| Dark faky blaes | 1 | 1 |
| Grey sandstone | 2 | 9 |
| Daugh | 0 | 2 |
| Coking coal } Kilsyth Coking Coal { | 2 | 10 |
| Daugh | 0 | 2 |
| Dark grey fakes | 1 | 6 |

According to the manager, Mr. Brand, the flow appeared as an oozing from the roof of the Coking Coal. It was spread uniformly, and never localised through any single channel. No sample of the oil has been preserved, but Mr. Brand stated that it

[1] 'A Study of Oil-Shales and Torbanites' *Trans. Geol. Soc., Glasgow*, Vol. XVI, Part II, 1917, p. 188.

was black and viscous, of specific gravity 0·860, and flash-point 92° Fahr. It yielded 56 tons in 1905-6.

The seepage took place over an area of 20 acres, and ceased in 1908, no trace of oil having been met since that year. The oil was drained with the water from the workings into the sump and then raised to the surface with the pit water.

The phenomenon occurred only at St. Flanans, and has not been observed in the other pits of the Kilsyth district. Cross-cut mines at St. Flanans itself show no oil, though minute quantities of ozokerite were seen in one of them.

The two most conspicuous features of the section in the district are: (1) a thick group of dark shales or blaes known as the 'Black Metals,' 10 fms. thick and occurring 27 fms. above the Coking Coal, and (2) a thick intrusive igneous rock which at this point is a short distance above the Black Metals. One hypothesis put forward is that the oil resulted from the action of the sill on the bituminous parts of the 'Black Metals.' As the sill changes its horizon, it is possible that at St. Flanans it was just at the distance required to produce the effect.

*Broxburn.*—An occurrence of native petroleum near Broxburn is described by Mr. D. R. Steuart in 'The Oil-Shales of the Lothians' (*Mem. Geol. Surv.*, 2nd Ed., 1912, pp. 166–7).

'As already mentioned, native petroleum was found near Broxburn in sedimentary strata about 10 fms. below the Dunnet Shale. In 1886, in No. 5 or Sandhole Pit, near the refinery, while cutting a level westward through inclined strata at the above mentioned position, there was a constant oozing of petroleum and brine, together with a strong smell of gas. A well was made, and the petroleum gathered at intervals for over a year. About 200 barrels in all were got. The specific gravity of the oil was ·830, the setting point (or highest temperature at which it congeals or ceases to flow, was 61° F. (16° C.). It had a brown colour by transmitted, and green by reflected light. Refined in the laboratory it produced :—

| | Per cent. |
|---|---|
| Naphtha - - - sp. gr. ·700 - | 5·0 |
| ,, - - - - ·730 - | 5·2 |
| Burning oil - - - ·802 - | 34·1 |
| Intermediate oil - - ·840 - | 10·5 |
| Lubricating oil - - - ·865 - | 16·7 |
| Solid Paraffin, M. pt. 103° F. (39·4° C.) | 12·5 |
| Loss in Refining - - - - | 16·0 |
| | 100·0' |

Two small occurrences of oil have been recently reported at Mid-Breich and at Westwood Pits, in the West Calder area. At both localities oil was got flowing from strata immediately below the Barracks Limestone. In the Westwood workings it was found oozing out of joints and cracks in a hard sandstone underneath the limestone in the neighbourhood of a fault cut in driving a stone mine. The oil flowed readily at first, but on

exposure soon stiffened to a slow-moving viscous and black material.

There was only a little oil at Westwood, but at Breich, from the same horizon, a larger and more constant flow occurred, from which it was possible to collect enough for analysis.

*St. Catherine's Well.*—The frequently mentioned occurrence of oil known as the Balm Well, is situated near Liberton, to the south-east of Edinburgh. The well is close to the great Pentland Fault, on its downthrow side, where the Oil-shale Series is let down against the sandstones of the Upper Old Red.

The oil is found floating on the surface of the water, and from a sample recently collected by Mr. D. Tait, has been shown to be a petroleum differing in some respects from crude oil derived from oil-shale.

About 20 years ago oil was met with on approximately the same horizon in making a deep drain nearly half a-mile south-west of Niddrie House and about $2\frac{1}{2}$ miles north of St. Catherine's Well. No very satisfactory account is now available, but it said that it had a specific gravity ·907, with flash point 280° F.

## Recent Explorations for Oil.

*Introduction.*—Actual drilling for free oil in Scotland commenced on the 14th June 1919, and has been conducted by Messrs. Pearson & Son, Ltd., who were appointed Petroleum Development Managers for the Mineral Oil Production Department of the Ministry of Munitions, and of which the control in this matter of drilling for oil in the United Kingdom has passed to H.M. Petroleum Department. The Petroleum (Production) Act of November 1918 gives free access by the Geological Survey to all shafts and borings for petroleum, to the specimens obtained, and to the journals kept. From the commencement of drilling in Scotland, Mr. David Tait has been detailed to visit the borings, to collect samples, and to examine and chronicle the results obtained.

The sites of the boreholes in Scotland, as in the case of those in England, were selected by the geologists attached to Messrs. Pearson's staff.

The system of drilling adopted produces only chips of rock with occasional fragments, derived from cavings, mixed with crushed and pulverised detritus. Samples are secured by a baler lowered down the hole after each 5 ft. of boring.

From a geological standpoint, therefore, the system of drilling is imperfect, and the determination of the thickness of thin bands of rock is often a matter of uncertainty.

## West Calder Boring.

(Commenced 14th June 1919; Finished October 1921.)

The boring is situated 366 yds. south-south-west of the United Presbyterian Church, West Calder, in 1-in. Geological Sheet 32; 6-in. Sheet, Edinburgh, 11 N.W., New Series.

Height above O.D. 600 ft. approx.

The boring commences in the Oil-Shale Group of the Calciferous Sandstone Series at an horizon a little below the Broxburn Shale, which, dipping west, has been mined to the outcrop a few yards west of the boring. At a depth of 300 to 330 ft. it passed through an oil-shale recognised by the local mining engineers as the Dunnet. So far as could be judged, the oil-shale proper is about 6 ft. thick, with an equal amount of shaly blaes above and below. About 438 ft. from the surface another oil-shale probably represents the Under Dunnet, a seam well known in the district though frequently not of economic value. A light brown freshwater limestone with entomostraca, and apparently 10 to 12 ft. thick, was entered at a depth of 618 ft. Below this the strata consist of 660 ft. of sandstone with intercalated bands of dark shale and a thin bed of oil-shale at 1,128 ft. A limestone 15 ft. thick containing entomostraca was entered at 1,290 ft.

From 1,305 ft. to 1,685 ft. the strata consist mainly of dark shales, with nothing of economic value. Between 1,685 ft. and 2,935 ft. the boring passed through a thick series of ash with occasional thin intercalations of black shale, and a bed 90 ft. thick between 2,510 and 2,604 ft. depth.

The ash rests on a basaltic rock, 47 ft. thick, with characters suggesting to Mr. E. B. Bailey a lava of somewhat later age than those of Arthur's Seat. Below the basalt the boring was continued in a thick series of black shales with subsidiary beds of ash at 3,420 ft. and 3,780 ft., down to the depth of 3,923 ft., when boring ceased, in sandy beds containing salt water.

The inflow of water occurred between the depths of 3,900 to 3,910 ft., at a rate of 180 galls. per hour. An analysis of a sample of this water collected by Messrs. Pearson & Son, and made at the Government Laboratory by Mr. A. G. Francis and Mr. J. Connah, is as follows :—

Specific Gravity at 60° F. 1·0630.

| | | |
|---|---|---|
| Calcium | 4·85 | grams per 1,000 grams. |
| Strontium | 0·88 | ,, |
| Barium | 0·48 | ,, |
| Magnesium | 1·49 | ,, |
| Sodium | 24·62 | ,, |

| | | |
|---|---|---|
| Potassium | 0·20 | grams per 1,000 grams. |
| Lithium | trace | ,, |
| Ammonium | 0·06 | ,, |
| Chlorine | 50·70 | ,, |
| Bromine | 0·62 | ,, |
| Carbonate ($CO_3$) | 0·04 | ,, |

It will be seen that below the Under Dunnet none of the oil-shale seams, such as the Pumpherston, Dalmahoy, Wardie, and Coalheugh shales have been identified. This was not unexpected, as they do not prove workable in the neighbourhood.

From the point of view of the main object of the boring, the distinctive character of the section, beyond the unexpected thickness of the ash, is the great proportion of argillaceous material and the absence of sandstones between 1,290 and 3,900 ft.

Shows of oil and gas were recorded at the following depths :—

| Depths in feet. | Gas or oil shows. |
|---|---|
| 525–540 | Gas. |
| 625–650 | Oil show in sandstone. |
| 725 | Gas. |
| 820 | Oil show in sandstone. |
| 945–955 | Gas show, 50,000 cubic feet. |
| 1,160 | Oil show in sandstone. |
| 2,610 | Oil show at top of ash. |
| 3,390 | Oil scum. |
| 3,900–10 | Salt water, analysis above. |

## D'Arcy Boring.

(Commenced 29th October 1919.)

The boring is situated one mile south-south-west of the mining village of Chesterhill (2½ miles south-east of Dalkeith) in 1-inch Sheet. Scotland 32; 6-inch, Edinburgh VIII, S.E.

Height above O.D., 750 ft. approx.

Progress was delayed at first owing to difficulties in obtaining a suitable supply of water.

The boring commenced in the Lower Limestone Group, on an horizon much higher in the Carboniferous sequence of Scotland than that at which the boring at West Calder started.

At D'Arcy the Lower Limestone Group rises in a clearly defined anticline forming a local fold along the general anticlinal uplift between the Roman Camp and Cousland, on the eastern side of the Midlothian Coalfield.

The boring is situated on the crest of this local anticline, and started a few feet below the outcrop of the D'Arcy Limestone (No. 2, or Skateraw Limestone).

The following abstract of the section is taken from the record drawn up by Mr. Tait from his examination of the samples obtained by the method mentioned on p. 58 :—

| | Thickness | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Crinoidal limestones interbedded with sandstones and shales (approximate base of Carboniferous Limestone Series) | 162 | 162 |
| Dark shales and reddish marl | 62 | 224 |
| Limestone, brownish | 2 | 226 |
| Dark shale and sandstone with marine organisms | 50 | 276 |
| White clay (fireclay or marl with white limestone) | 30 | 306 |
| Limestone, grey, crinoidal | 2 | 308 |
| Dark shale with sandstone and fireclay beds (shows of oil at 493 to 498 ft.) | 228 | 536 |
| Limestone, light-coloured, concretionary, with thin coal and fireclay below | 2 | 538 |
| Sandstone and grey marl | 15 | 553 |
| Marl, light grey, with limestone concretions | 2 | 555 |
| Fireclay with sandstone bands and thin coal | 32 | 587 |
| Sandstone, hard, fine-grained, yellowish, with traces of oil (596 to 615 ft.) | 38 | 625 |
| Fireclay, with thin coaly beds | 45 | 670 |
| Shale, dark | 35 | 705 |
| Oil-shale, *see* p. 49 | 15 | 720 |
| Shale, calcareous with *spirorbis* ($\frac{1}{6}$ in. to $\frac{3}{4}$ ft.) | — | — |
| Sandstone, hard, fine-grained (gas given off at 724 ft. at a rate of 30,000 cubic ft. in 24 hours) | 8 | 728 |
| Sandstone and shale with traces of coal | 27 | 755 |
| Limestone, creamy-white, with greenish clay | 10 | 765 |
| Sandstone, with greenish marl | 55 | 820 |
| Dark and black shale, thin coal, fish remains, plant fragments | 15 | 835 |
| Shale, dark, sandy, traces of coal | 11 | 846 |
| Sandstone, fine-grained, with marly shale bands, traces of oil at 906 ft. | 69 | 915 |
| Shale, dark, with thin coal and fireclay | 15 | 930 |
| Dark and black shale | 70 | 1,000 |
| Sandstone, fine-grained | 40 | 1,040 |
| Dark shale with ironstone nodules | 10 | 1,050 |
| Sandstone, grey, fine-grained | 10 | 1,060 |
| Dark shale, bituminous | 10 | 1,070 |
| Dark shale with thin coal | 7 | 1,077 |
| Marl, mottled red and green | 53 | 1,130 |
| Dark shales, with fish scales and entomostraca | 6 | 1,136 |
| Sandstone, light grey, hard, fine-grained | 11 | 1,147 |
| Limestone, light-coloured, splintery, with entomostraca | 3 | 1,150 |
| Dark shale with traces of coal | 13 | 1,163 |
| Fireclay | 7 | 1,170 |
| Limestone, splintery, with entomostraca | 3 | 1,173 |
| Marly shale or fireclay with thin coal | 7 | 1,180 |
| Dark shale | 5 | 1,185 |
| Limestone, dark-brown, bedded, with entomostraca and plant remains | 2 | 1,187 |
| Dark shale with thin coal | 13 | 1,200 |
| Dark crumbly shale, with entomostraca | 69 | 1,269 |
| Limestone, brownish, sandy | 1 | 1,270 |

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Shale, dark, well-bedded, with nodules, entomostraca and plant-remains | 23 | 1,293 |
| Light-coloured clay with limy concretions | 20 | 1,313 |
| Dark shale with entomostraca and plant-remains | 10 | 1,323 |
| Grey marl or fireclay | 30 | 1,353 |
| Dark shale with lamellibranchs | 15 | 1,368 |
| Coal, bright | 2 | 1,370 |
| Fireclay | 2 | 1,372 |
| Sandstone | 6 | 1,378 |
| Dark shale, bituminous (1,400–5 ft.) | 42 | 1,420 |
| Dark shale, crinoid ossicles, lamellibranchs | 28 | 1,448 |
| Sandstone, pale greenish, or sandy marl | 2 | 1,450 |
| Limestone, brownish yellow, splintery | 3 | 1,453 |
| Shale, dark | 20 | 1,473 |
| Sandstone, dark brown, traces of oil | 17 | 1,490 |
| Dark shale, lamellibranchs | 10 | 1,500 |
| Sandstone, hard, dark | 10 | 1,510 |
| Dark shale, ironstone nodules | 30 | 1,540 |
| Dark calcareous shale with crinoid ossicles | 14 | 1,554 |
| Limestone, grey sandy, crinoidal | 2 | 1,556 |
| Dark calcareous shales, crinoid ossicles, brachiopods | 49 | 1,605 |
| Dark shale with *Lingula* | 13 | 1,618 |
| Sandstone | 17 | 1,635 |
| Dark shale, irony nodules or ribs | 20 | 1,655 |
| Sandstone, medium to fine-grained, with water | 17 | 1,672 |
| Fireclay and thin coal | 2 | 1,674 |
| Dark shales, slickensided, ironstone nodules, with fish-scales and entomostraca | 80 | 1,754 |
| Limestone, splintery, brownish-grey, entomostraca | 3 | 1,757 |
| Grey marly shale, small gasteropods (*Platyostomella*) | 9 | 1,766 |
| Sandstone, grey, fine-grained | 19 | 1,785 |
| Dark clayey shale, entomostraca | 8 | 1,793 |
| Limestone, brownish, entomostraca | 2 | 1,795 |
| Dark shale | 12 | 1,807 |
| Sandstone, quartzose, rather fine-grained, soft, grains rounded to sub-angular. Flow of oil between 1,810–20 ft. | 13 | 1,820 |

At the depth of 162 feet the boring enters the Oil-shale Series, but since the Burdiehouse Limestone is not recognisable the position in the sequence of the sandstone at the bottom of the boring is not certain. The occurrence of *Platyostomella* below strata containing crinoids recalls the section along the shore in East Fifeshire, where several hundred feet of alternating beds of sandstone and shale occur below the highest bed containing this fossil.[1] At D'Arcy it is not possible to state definitely what would be the thickness of the Oil-shale Series below the present depth (1,820 ft.) of the boring, though local evidence points to a considerable diminution in thickness as compared with the section in Eastern Fife.

[1] 'The Geology of Eastern Fife' (*Mem. Geol. Surv.*), 1902, pp. 88–99.

The following report by Mr. E. M. Bailey, of the Pumpherston Works, on a sample of the crude petroleum received 13th May 1922, is given in *Oil News* :—[1]

'Specific Gravity at 60 deg. F., ·823.
Setting Point, 66 deg. F.
Flash Point, very much below 73 deg. F.

The crude oil yielded refined products as follows :—

| Refined Product. | Galls. per 100 Galls. | Sp. Gr. at 60° F. | Flash Point. | Setting Point. |
|---|---|---|---|---|
| Motor Spirit | 12·50 | ·727 | — | — |
| Heavy Naphtha | 2·63 | ·771 | — | — |
| Kerosene | 19·65 | ·7855 | over 100° F. | — |
| Heavy kerosene or Light Gas oil | 5·79 | ·808 | — | — |
| Gas oil | 17·57 | ·832 | 246° F. | 41° F. |
| Lubricating oil | 15·00 | ·878 | 378° F. | 23° F. |
| Wax | 13·36 | — | — | — |
| Residuum | 3·66 | — | — | — |
| Total | 90·16 | — | — | — |

'This is a crude petroleum of good quality, having an iodine absorption of 2·92 per cent. It yields fair percentages of motor spirit and kerosene of good quality, as well as a large percentage of solid paraffin wax. The products are easily refined, and the paraffin is readily extracted under certain conditions yielding a crude solid paraffin or "scale" of excellent quality and of very pale colour, which on sweating yields a good wax.'

On May 8th the oil rose to 1,675 feet from the surface.

A sample of water obtained by Messrs. Pearson from a depth of 905 ft., and analysed at the Government Laboratory by Mr. A. G. Francis, gives :—

Specific gravity at 60° F., 1·0038—

| | |
|---|---|
| Calcium | 10·12 parts per 100,000. |
| Strontium | 0·46 ,, |
| Barium | 0·41 ,, |
| Magnesium | 3·57 ,, |
| Sodium | 181·31 ,, |
| Potassium | 1·46 ,, |
| Lithium | trace ,, |
| Ammonium | 0·81 ,, |
| Carbonate ($CO_3$) | 23·70 ,, |
| Sulphate ($SO_4$) | 5·20 ,, |
| Chlorine (Cl) | 272·83 ,, |
| Bromine (Br) | 2·90 ,, |
| Silica | 0·40 ,, |

The sample contained a small yellow deposit of iron oxide, which was filtered off. The clear filtrate was colourless and had a very faint odour of petroleum.

[1] No. 499, 24 June, 1922, p. 673.

# INDEX.


Aberdeen, 43.
Adamhill, 29.
Airdrie, 16.
Allans, 11.
Allt a' Ghuaill, 39.
Almond River, 43.
*Ammonium Sulphate* from :—
  Arniston Parrot Coal, 7.
  Carron Two-foot Coal, 15.
  Earl David's Parrot, 24.
  Edmondstone, 9.
  Gas Coal, Ayrshire, 26.
  Great Seam, 8.
  Main Coal, Ayrshire, 27.
  Miller Coal, 15.
  Oil-Shale Group, 44.
  Pirnie Parrot, 24.
  Raasay Oil-Shale, 55.
  Shale Coal, N. Ayrshire, 28.
  Skye Oil-Shale, 56.
  South Parrot, Niddrie, 9.
  Torbanehill, 44.
  Wardie Shale, 48.
*Analyses* :—
  Brora Coal, 35, 36.
  —— Shale, 35.
  Crossgatehall Parrot Shale, 6.
  Five-foot Coal (New Cumnock), 29.
  Linn Bed Coal, 29.
  Loch Cuither, coal at, 37.
  Major Coal, 29.
  Oil, D'Arcy, 63.
  Parrot Coal (Fergushill), 29.
  Rhums (Loanhead), 9.
  Shale Coal (N. Ayrshire), 28.
  South Parrot, Old Cowden Cleugh, 10.
  Swallowdrum Coal, 21.
  Tourha' Coal, shale of, 29.
  Vaternish, lignite of, 43.
  Water, D'Arcy Boring, 63.
  —— West Calder Boring, 59, 60.
  Wild Parrot (Loanhead), 9.
An Ceannaich, 43.
Anderson, A. & G., 2.
Andrews Coal, 5.
An Dunan, 40.
Annandale, 28.
Annick Lodge, 28.
Applecross, 54.
Arden, 15.
—— Coal Co., 2.
Ardnamurchan, 38.
Ardtornish Towers, 41.
Ardtun, 40, 41.
Argyll, Duke of, 40, 41.
Argyllshire Coalfield, 30.
Armadale, 14.
Arniston Colliery, 7.
—— Parrot Coal, 5, 6, 7.
Avon Water, 50.
Auchengray, 49.
Auchenharvie, 28.
Auchenheath, 12.
—— Oil Coal, 12.
Auchterderran, 23, 24.
Ayrshire Coalfield, 25–30.

Back Coal, 17.
Bailey, E. B., 59.
—— E. M., 63.
Baird, Wm., & Co., 2.
Balbardie Gas Coal, section of, 13.
Balm Well, 58.
Banknock, Shale Coal of, 15.
Barracks Limestone, 57.
Barr, W., Ltd., 2.
—— Colliery, 27.
Barrmill, 25, 27.
Bathgate, 13.
—— Hills, 43, 49.
Bearreraig, 55.
Beggar Coal, 5.
Béin-anini, 38.
Beinn an Aoinidh, 38, 39.
Beith, 26.
Bent Colliery, Splint Coal, section of, 16.
Ben Tianavaig, 56.
Big Drum Coal, 17.
—— Parrot Coal, 13.
Bilston Burn, 6, 9, 10.
—— —— Limestone, 5.
Binnend, 43.
Birkenshaw, 15.
Blackbird Coal, 5.
Blackchapel Coal, 5.
Blackstone, section at, 11.
Blackwood, 12.
Blairhall, section at, 22.
—— Ironstone, 21, 22.
Blue Coal, 5.
Boghead Cannel Coal, 14.
—— Coal, 12.
Boig Coal, 29.
Borestone Coal, 25.
Bothwell, 16.
Braehead, 50.
Brand, Mr., 56.
Bredisholm, 16.
Broadford, 42.
Brora, 30, 31, 32.

Brora Coalfield, 32–36.
——— ——— reserves, 35.
——— River, 34, 35, 37.
——— Shale, 35.
——— Wool Mill, 34.
Brown, J. & W., 2.
Browns Coal, 5.
Browshot, 50.
Broxburn, 44, 57.
——— Oil-works, 55.
——— Shale, 59.
Bryans Splint Coal, 5.
Bunessan, 40, 41.
Burdiehouse Limestone, 62.
Burgh Head, 41.
Burghlee Pits, 7.
Burnbank, 29.
Burntisland, 43.
Bush Coal, 23.

Cadell's Parrot Coal, 22.
Cadh' an Righ, 36.
Caldwell, 26.
Camastianavaig, 56.
Campbeltown Coalfield, 30.
Campsie, 12.
Canna, lignite of, 43.
Capeldrae, 23.
——— Parrot Coal, 22, 23.
Caprington and Auchlochan Collieries, Ltd., 2.
Carberry Colliery, 8.
Carleton Coal, 5.
Carlops, 48, 49.
Carluke, 49.
Carnwath, 49, 50.
Carron Co., 2.
——— Two-foot Coal, 15.
Carruthers, R. G., 50.
Carsaig, 38, 39, 40.
Castlecary Limestone, 51.
Castle Douglas Colliery, 17.
Central Coalfield, 10–16.
Cheese Bay, 52.
Chesterhill, 60.
Clarkston, 14.
Clay Gas Coal, 27.
Cleugh Pits, 12.
Climpy, 13.
——— Gas Coal, 13.
Clippens, 11, 12.
——— Oil Co., 43.
Clough, C. T., 40, 41, 51.
Coalburn, 17.
Coalheugh Shale, 60.
Cobbinshaw, 49, 50.
Colinburn Coal, 14.
Coltness Iron Co., 2.
Comrie Ironstone, 22.
Conacher, H. R. J., 33, 46, 56.
Coneypark, 15.
Connah, J., 59.
Conurdan, 41.
Corbie Craig Coals, 5.
——— Jewel Coal, 5.
——— Splint Coal, 5.
Coronation Coal, 5.
Cot Castle, 50.
Cousland, anticline at, 60.
Cove Harbour, 51.
——— Oil-Shale, 51, 52.
Cowdenbeath Colliery, section at, 21.
Cowden Pit, 7.
Craigie Coal, 27.
Craw (Crow) Coal, 14.
Creoch Coal, 30.
Cromarty, 37.
Crosscroes, section at, 14.
Crossford, 12.
Crossgate Hall Parrot Shale, 6.

Dailly Coalfield, 27.
Dalgain, 26.
Dalkeith, 49, 60.
Dalmahoy Shale, 60.
Dalry, 25.
——— Clayband Ironstone, 26.
D'Arcy, 49, 62.
——— Boring, description, 60–63.
——— Limestone, 49, 60.
Dearg Bhealach, section at, 38, 39.
Denhead, 18.
Diamond Coal, 5.
——— ——— No. 1, 5.
——— ——— No. 2, 5.
Dixon, J. S., 35.
——— W., Ltd., 2.
Doubster Oil-Shale, 51.
Douglas Coalfield, 17.
——— Water, 17.
Doura, 28.
Dron, R. W., 26, 30.
Dross Coal, 17.
Drum, 17.
Drumcarrow, 20.
Dryden Burn, 10.
——— March, 7.
Dunbar, 48, 51, 52.
Dunfermline, 18, 21.
——— Splint Coal, 21.
Dun Caan, 54.
——— Limestone, 51.
Dunn, H. Shaw, 30.
Dunnet Shale, 57, 59.
Dunrobin Castle, 31.
Dunvegan, 42.
Dysart, 24.
——— Coalfield, 23–25.

Earl David's Parrot Coal, 23, 24.
Eas Dubh, 40.
East Kilbride, 50.
Easton Colliery, section at, 13.
East Roughrigg, 14.
Eathie, 37.
Eddlewood Colliery, section of Splint Coal, 16.
Edgefield, section at, 9.
Edinburgh, 43.
Edmondstone Cannel, section of, 9.
——— Parrot, 5.
Elgin Bleachfield Bore, 20.
——— Ironstone, 21.
Ell Coal, 17, 28.
Estuarine Series, 52.

Fallowhill Coal, 17.
Faskally, 35, 37.
Fauldhouse, 51.
Fergushill, 28, 29.
Fife Coal Co., 2.
Fifeshire Coalfield, 18–25.
Five-foot Coal, 5, 8, 29.
Flex Coal, 5.
Flockhouse, 23.
Forbes, E., 37.
Foul Coal, 13.
Four-foot Coal, 5, 17.
Francis, A. G., 59, 63.
Fraser Shales, 50, 51.

Gallatown, 24.
Garallan Coal Co., 2.
*Garantiana*, zone of, 52.
Gardner, Starkie, 37, 40, 41.
Garrion Burn, 15.
Gas Coal, Falkirk, 14.
Gatend Colliery, 27.
Gauchalland, 29.
Geikie, Sir A., 39, 43.
Gemmell, J., 18.
General's Rock, 48.
Gillespie Coal, 5.
Gillhead Bridge, 15.
Gilmerton Ironstone, 5, 6.
——— Limestone, 5, 6.
Glasgow Iron and Steel Co., 2.
Glass Coal, 5.
Glassee Coal, 21.
Glenbuck, 17, 26, 27.
Glenelg, 42.
Glenmavis, 15.
Gowanbrae, 41.
Granton, 46, 48.
Grasshill, 26, 27.
Great Glen Fault, 36.
——— Oolite, 32.
——— Seam Coal, 5.
Great Seam of Niddrie, 6, section of, 8.
Greendykeside, 15.
Greenfield, 16.
Greengairs, 15, 16.
Greenhead, 11.
Gribun, 41.
Grimset, 42.
Grocheard, 42.
Guelt, 27.
Gullane, 52.
Gunn, W., 51.

Halbeath, 21.
Hamilton Palace, 16.
Hard Splint Coal, 5.
Hare Burn, 10.
Harker, A., 42.
Haywood, 12.
Heddle, M. F., 43.
Heer, O., 37.
Helmsdale, 37.
Hirst Coal Co., 2.
Hislop, G. R., 21.
Hole Burn, 50, 51.
Holm, 31, 56.
Home Farm Colliery, section of Splint Coal, 16.
Hurlet Limestone, 6.
Hurlford, 29.
——— Main Coal, 28, 29.

Inchinnan, 11.
Index Limestone, 5, 9.
Innerwick, 52.
Innimore Lodge, 40.
Inverbrora Links, 34.
Inverkeithing, 43.
Inzievar Ironstone, 21, 22.

Jameson, R., 38, 39.
Jet, 31, 37.
Jewel Coal, 5.
——— ——— Bathgate, 13.
Johnstone Coal, 5.
——— Shale Coal, 11.
Joppa, 8.
Judd, Prof. J. W., 31, 32, 34, 36, 37.

Kailblades Coal, 5.
Kames, 26.
Kellaways Rock, 32, 34, 36.
Kelty, 18.
Kennoway, 22.
Kettle, 20.
Kidston, R., 52.

Kilbirnie, 26.
Kilmarnock, 28, 43.
Kilmaurs, 25.
Kilmux, 22.
Kilrenny (Fife), 43.
Kilsyth, 56, 57.
——— Coking Coal, section of, 56.
Kiltongue Musselband Shale, section of, 14, 15.
Kilwinning, 28.
Kinglassie Coalfield, 24.
Kinneil, 13.
Kirkcaldy, 18.
Kirkroad Coal, 17.
Kittlepurse Coal, 5.
Kittymuir, 15.

Lady Victoria Shaft, 7, 10.
Laigh Brocklar, 26.
——— Netherfielddyke, 50.
——— Walkerdyke, 50.
Lamancha, 48.
Lanark, 17, 43.
LANDALE, D., 20, 25.
Lanemark Coal, 29.
Langside, 26.
Largoward, 20.
Larkhall, 15.
Lassodie, 18.
Lesmahagow, 17.
———— Main Gas Coal, 12, 17.
Leven, 24.
——— Coalfield, 23–25.
Levenseat, 51.
Liberton, 58.
Lillies Coal, 11.
*Lingula*, 51, 62.
Linhouse Water, 43.
Linn Bed Coal, 27, 29.
Linwood, 11.
Little Gillespie Coal, 5.
——— Parrot Coal, 28.
——— Splint Coal, 5.
Loanhead, 9.
———— No. 1 Ironstone, 5, 6.
———— No. 2 ———— 5, 6, 7.
———— No. 3 ————5, 6, 7, 8.
Lochgelly, 18, 22.
———— Blackband Ironstone, 21, 22.
Lochgelly Iron and Coal Co., 2.
———— Parrot Coal, 21.
Loch, *see* Lochs.
Lochore, 22, 23.
Lochs :—
Aline, 41.
Cuither, 36.
Grisornish, 42.
na Keal, 41.
Scridain 41.
Lochs (*continued*) :—
Sligachan, 41.
Uig, 42.
Longcraig Limestone, 52.
Longriggend, 15, 16.
Lothian Coal Co., 2.
Lower Cove Limestone, 51.
——— Dysart Coal, 23, 24.
——— Gas Coal, 29.
——— Lias, 31.
——— Parrot, section of, 13.
Lumbo, 18, section at, 20.

MACCALLUM, D. A., 36.
MACCONOCHIE, A., 52.
MACCULLOCH, J., 40, 41–42.
Macdonald Coal, 17.
———— Limestone, 17.
MACDONALD, LORD, 42.
MACKENZIE, SIR G., 36.
Main Cannel Coal, 29.
—— Coal (Brora), 32.
—— —— (Campbeltown), 30.
—— —— (Dailly), 27.
Major Coal, 27, 29.
Mansfield Colliery, 30.
Markinch, 24.
Marr's Pool, 51.
Mavisbank, section at, 9.
McNaught Coal, 27, 29.
Methil, 24.
Mid Breich, 57
Middle Oolite, 37.
Middleton, 11.
Mill Coal, 14.
Miller Coal, 15.
MILLER, HUGH, 33.
Milliken, 11, 12.
Mineral Oil, 56–63.
Moffats Coal, 5.
Montgreenan, 28.
MOORE, A. G., 2.
Morvern, 41.
Motherwell, 16.
Mount Melville, 18.
Muircockhall Colliery, 21.
Muiredge, section at, 18.
Muirhall, 50.
Muirkirk, 17, 26.
Mull, lignite of, 37–41.
Mungle Shell Bed, 50.
MURCHISON, SIR RODERICK, 31, 33, 34, 36.
MURRAY, SIR DAVID, 38.
Mynheer Coal, 21.

Navidale, 37.
Netherfield Coal, 51.
———— Limestone, 51.

Newbattle Colliery, 7, 8.
New Cumnock, 27, 29.
—— ———— Collieries, Ltd., 2, 29.
Newtongrange, 9, 10.
Niddrie, 8, 9.
———— Colliery, 8.
———— House, 58.
———— North Junction, 8.
———— No. 13 Pit, 9.
Nine-foot Coal, 26, 27.
North Berwick, 52.
—— Coal, 5.
—— Greens Coal, 5, 6.
—— ———— Limestone, 5, 6.

Oakley, 22, 23.
———— Ironstone, 22.
———— Parrot Coal, 23.
Oil-Shales :—
Characters of, 43–46.
Berwickshire, 51.
Central Coalfield, 49–51.
Haddingtonshire, 51.
Midlothian, 46–48.
Raasay, 52, 55.
Skye—N.E., 55, 56.
Oil Works, Annick Lodge, 28.
—— ———— Pathhead, 30.
Oil, Yield of :—
Arniston Parrot Coal, 7.
Boghead Cannel Coal, 14.
Brora Parrot Coal, 33.
Cannel, Castle Douglas Colliery, 17.
Capeldrae Parrot Coal, 23.
Carron Two-foot Coal, 15.
D'Arcy, 63.
Great Seam, 8.
Kilsyth Coking Coal, St. Flanans, 57.
Kiltongue Musselband Shale, 14, 15.
Levenseat Shale, 51.
Lochgelly Parrot Coal, 21.
Main Coal, Campbeltown, 30.
—— —— Dailly, 27.
Miller Coal, 15.
Muiredge Oil-Shale, 18.
Nine-foot Coal, Douglas, 17.
Parrot Rough Coal, 10.
———— Shale Coal, 28.
Pirnie Parrot Coal, 24.
Raasay Oil-Shale, 55.
Sandhole Pit, 57.
Shale Coal, Clippens, 12.
———— —— N. Ayrshire, 28.
Six-foot Coal, Douglas, 17.
Skye Oil-Shale, 56.
Oil, Yield of (*continued*) :—
South Parrot, Niddrie, 9.
Splint Coal, Bredisholm, 16.
—— —— Douglas, 17.
Stairhead Coal, 8.
Torbanehill Coal, 14.
Wardend Gas Coal, 25.
Wardie Shale, 48.
Wee Gas Coal, 12.
Westfield Oil-Shale, 24.
Old Square Pit, 7.
Ollach, 55.
Overton Parrot, 23.
Oxford Clay, 32.

Paisley, 43.
Parrot Coal, Brora, 32.
———— —— Dailly, 27.
———— —— Fife, 23.
———— —— Stevenston, 28.
———— —— Rough Coal, 5, 10.
———— —— Shale, N. Ayrshire, 28.
Pathhead, New Cumnock, 30.
Peach, B. N., 52.
Peacock Coal, 5.
Peacocktail Coal, 5.
Pearson and Son, Ltd., 58, 59, 63.
Penicuik, 9.
———— House, 10.
Pennyghael, 39.
Penston Ironstone, 5.
———— Rough Coal, 5.
———— Splint, 5.
*Pila*, 46.
Pirleyhill Bridge, 15.
Pirnie Parrot Coal, 23, 24.
Pitcorthie, 18.
Pittencrieff Ironstone, 21.
*Platyostomella*, 62.
Pollard, W., 6, 10.
Polton, 10.
Ponfeigh, 17.
Portobello East Junction, 8.
Portree, 31, 36, 41, 42, 55.
Port Seton, 48.
Portsoy, 33.
Prince Charles's Cave, 56.
*Productus*, 51.
Pumpherston Shale, 60.
———— Works, 63.

Raasay, Oil-Shale of, 54, 55.
Raebog, 15.
Raeburn Shale, 50.
Rameldry, section at, 20.
Ramsay Pit, 7.
Rawyards, 14, 16.

Real Corbie Coal, 5.
*Reinschia*, 46.
Rhums, 8; analyses, 9.
Riddell, Sir J., 38.
Rigside, 17.
Robb Coal, 17.
Robertson, T., 8.
Robertson, J. B., 45.
Rochsoles, 3, 14.
Roman Camp, anticline at, 60.
Roof Bed, 32.
Rosewells, 23.
Roslin Colliery, 7.
Rough Coal, 5.
Rumbles Coal, 8.
Russell, A., Ltd., 2.
Ryden, 14.

St. Abb's Head, 51.
St. Catherine's Well, 58.
St. Flanans, 56, 57.
Saltcoats, 28.
Sandhole Pit, 57.
Schoolyard Pit, 13.
Schuster, J., 46.
Scoribreck, 41.
Screapadal, 55.
Scremerston Coals, 51.
Secondary Coals, 30–37.
Seven-foot Coal, Fife, 23.
———— —— Muirkirk, 26.
Shale Coal, 12; sections of, 15; North Ayrshire, 28.
Shandwick, 36.
Shiaba, 40.
Shotts Gas Coal, 14.
——— Iron and Steel Co., 2.
Silver Willie Coal, 5.
Six-foot Coal, 13, 17.
Skateraw Limestone, 49, 60.
Skaterigg Coal, 17.
Skye, Lignites of, 41–43.
——— Secondary Coals of, 36–37.
——— Upper Lias of, 31.
Slamannan, 15, 16.
Smith, A., 36.
Smithy Coal, 5, 17.
Sorn, 26.
South Coal, 5.
Southfield, 15.
South Parrot, analysis of, 10.
—— ——— Coal, sections of, 9.
*Spirorbis*, 61.
Splint Coal, 14, 17.
Staffin, 36.
Stairhead Seam, 5, 6, 7.
———— section of, 8.
Stanhope, 38.
Stanrigg Oil Works, 16.
Steuart, D. R., 15, 55, 56, 57.
Stevenston, 28.
Stinkie Coal, 5.
Stoneypath Coal, 17.
Stony Coal, 5, 6, 7, 17.
Storab's Grave, 55.
Straiton, 43, 49.
Strathaird, 42.
Strathaven, 50.
Strathsteven, 34, 35.
Sulphate of Ammonia, *see Ammonium Sulphate.*
Sulphury Coal (Dailly), 27.
Summerhouse Park, 31.
Summerlee Iron Co., 2.
Sutherland, Jane, Countess of, 34.
Sutherland, John, Earl, of, 31, 37.
Swallowdrum Coal, 21.
Sweet Dub Pit, 24.
Swinhill, 15.

Tait, D., 31, 58, 61.
Talisker, 41.
Tannochside, 16.
Tarbrax, 49.
*Telangium affine*, 51.
Tertiary Coals, 37–43.
———— Lignites, 37–43.
———— ———— Canna, 43.
———— ———— Mull, 37–41.
———— ———— Skye, 41–43.
Thirty-inch Coal, 17.
Thorntonloch, 52.
Three-foot Coal, 5, 26, 27.
Torbanehill Coal, 14, 44.
Torr Mor, 41.
Tourha' Coal, 27, 29.
Tranent Splint Coal, 5.
Traquair, R. H., 52.
Trinity, 48.
Trotternish, 42.
Twechar, 56.
Two-foot Cherry Coal, 5.

Uddingston, 16.
Under Dunnet Shale, 59, 60.
Union Coal, 5.
United Collieries, Ltd., 2.
Uplawmoor, 26.
Upper Cove Limestone, 51.
—— Comrie Ironstone, 22.
—— Gas Coal, 29.
—— Lias, 31.
—— Oolite, 37.

Vaternish, Lignite of, 43.
Victoria Pit, section at, 24.
Viewpark, 16.
Virtuewell Coal, 14, 15, 16.

Waddell and Son, 2.
Walkerdyke Coal, 50.
Walkinshaw, 11.
Wallyford Colliery, 8.
Wardend Colliery, section at, 25.
——— Gas Coal, 25.
Wardie Shales, section of, 48, 52, 60.
Water of Brora, 35.
Waverley Coal, 5.
Wee Coal (Dalry), 26.
—— Drum Coal, 17.
—— Gas Coal, 12.
—— Parrot Coal (Flockhouse), 23.
Wemyss Coalfield, 23–25.
——— Parrot Coal, 25.
West Calder, 57.
—— ——— Boring, description of, 59–60.
Westfield (Fife), 24.
West Glentore, 15.
—— Wemyss, 24.
Westwood Pits, 57, 58.
Whitehill, 10.
Wilderness, 41.
Williams, John, 34.
Wilsons and Clyde Coal Co., Ltd., 2.
Wilsontown, 12.
——— Gas Coal, 12.
Windyedge Pit, 29.
Wishaw Coal Co., 2.
Wishaw, Shale Coal of, 15.
Wood Coal, 17.
——— —— (Fife), 23.
Woodend Limestone, 51.
Woodhall Coal Co., 2.
Woodward, H. B., 31, 32, 35.
Woolmet, 7.

## SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN.

| | s. | d. |
|---|---|---|
| VOL. I. TUNGSTEN AND MANGANESE ORES. By H. Dewey and C. E. N. Bromehead, B.A., with contributions by T. Eastwood, A.R.C.S., G. V. Wilson, B.Sc., and R. W. Pocock, B.Sc.. 59 pp. 2 illustrations. Wrapper (1915; Edit. 3, *in preparation*) | | |
| VOL. II. BARYTES AND WITHERITE. By G. V. Wilson, B.Sc., T. Eastwood, A.R.C.S., R. W. Pocock, B.Sc., D. A. Wray, M.Sc., and T. Robertson, B.Sc., with contributions by H. G. Dines, A.R.S.M. 119 pp. 6 plates. 1 text figure. Wrapper. (1915; Edit. 3, 1922) | 3 | 0 |
| VOL. III. GYPSUM AND ANHYDRITE. By R. L. Sherlock, D.Sc., and B. Smith, M.A.; AND CELESTINE AND STRONTIANITE. By R. L. Sherlock, D.Sc. 64 pp. 4 illustrations. Wrapper. (1915; Edit. 2, 1918) | 2 | 0 |
| VOL. IV. FLUORSPAR. By R. G. Carruthers, R. W. Pocock, B.Sc., and D. A. Wray, B.Sc., with contributions by H. Dewey, and C. E. N. Bromehead, B.A. 39 pp. 2 illustrations. Wrapper (1916; Edit. 2, 1917) | 0 | 9 |
| VOL. V. POTASH-FELSPAR, PHOSPHATE OF LIME, ALUM SHALES, PLUMBAGO OR GRAPHITE, MOLYBDENITE, CHROMITE, TALC AND STEATITE (SOAPSTONE, SOAP-ROCK AND POTSTONE), DIATOMITE. By A. Strahan, Sc.D., LL.D., F.R.S.; J. S. Flett, D.Sc., LL.D., F.R.S.; and C. H. Dinham, B.A., with contributions by C. T. Clough, M.A.; T. Eastwood, A.R.C.S.; and A. F. Hallimond, B.A. 43 pp. 3 illustrations. Wrapper. (1916; Edit. 2, 1917) | 1 | 0 |
| VOL. VI. REFRACTORY MATERIALS: GANISTER AND SILICA ROCK, SAND FOR OPEN-HEARTH STEEL FURNACES, DOLOMITE. RESOURCES AND GEOLOGY. 241 pp. 3 plates. 8 text figures. Wrapper - - (1918; Edit. 2, 1920) | 7 | 6 |
| VOL. VII. MINERAL OIL, KIMMERIDGE OIL SHALE, LIGNITES, JETS, CANNEL COALS, NATURAL GAS. ENGLAND and WALES. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., with contributions by W. Gibson, D.Sc., H. Dewey, B. Smith, M.A., C. E. N. Bromehead, B.A., and J. Pringle. 125 pp. 1 plate. 7 text figures. Wrapper - - (1918 Edit. 2, 1920) | 5 | 0 |
| VOL. VIII. Iron Ores: HÆMATITES OF WEST CUMBERLAND, LANCASHIRE AND THE LAKE DISTRICT. By B. Smith, M.A. 182 pp. 4 plates. 29 text figures. Wrapper - - (1919) | 9 | 0 |
| VOL. IX. IRON ORES (*contd.*). SUNDRY UNBEDDED ORES OF DURHAM, EAST CUMBERLAND, NORTH WALES, DERBYSHIRE, THE ISLE OF MAN, BRISTOL DISTRICT AND SOMERSET, DEVON AND CORNWALL. By T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and H. Dewey. 87 pp. 7 text figures. Wrapper - - - - - - (1919) | 3 | 6 |
| VOL. X. IRON ORES (*contd.*). THE HÆMATITES OF THE FOREST OF DEAN AND SOUTH WALES. By T. F. Sibly, D.Sc. 93 pp. 14 text figures. Wrapper - - - (1919) | 4 | 0 |
| VOL. XI. IRON ORES (*contd.*). THE IRON ORES OF SCOTLAND. By M. Macgregor, B.Sc.; G. W. Lee, D.Sc.; G. V. Wilson, B.Sc.; with contributions by T. Robertson, B.Sc., and J. S. Flett, F.R.S. 240 pp. 18 text figures - - (1920) | 10 | 0 |
| VOL. XII. IRON ORES (*contd.*). BEDDED ORES OF THE LIAS, OOLITES AND LATER FORMATIONS IN ENGLAND. By G. W. Lamplugh, F.R.S., C. B. Wedd, B.A., and J. Pringle. 240 pp. 8 plates. 12 text figures. Wrapper - - - (1920) | 12 | 6 |

| | s. | d. |
|---|---|---|
| VOL. XIII. IRON ORES (*contd.*). PRE-CARBONIFEROUS AND CARBONIFEROUS BEDDED ORES OF ENGLAND AND WALES. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S.; W. Gibson, D.Sc.; T. C. Cantrill, B.Sc.; R. L. Sherlock, D.Sc., and Henry Dewey. 123 pp. 3 plates. 10 text figures. Wrapper - (1920) | 7 | 6 |
| VOL. XIV. REFRACTORY MATERIALS: FIRECLAYS. RESOURCES AND GEOLOGY. 243 pp. 4 plates. 13 text figures. Wrapper (1920) | 8 | 0 |
| VOL. XV. ARSENIC AND ANTIMONY ORES. By Henry Dewey, with contributions by J. S. Flett, O.B.E., LL.D., D.Sc., F.R.S., and G. V. Wilson, B.Sc. 59 pp. 1 plate. 2 text figures. Wrapper - - - - - - - (1920) | 3 | 0 |
| VOL. XVI. REFRACTORY MATERIALS: GANISTER AND SILICA-ROCK, SAND FOR OPEN-HEARTH STEEL FURNACES, DOLOMITE. PETROGRAPHY AND CHEMISTRY. By Herbert H. Thomas, M.A., Sc.D., A. F. Hallimond, M.A., and Ernest G. Radley. 115 pp. 7 plates. 6 text figures. Wrapper - - - (1920) | 5 | 0 |
| VOL. XVII. THE LEAD, ZINC, COPPER AND NICKEL ORES OF SCOTLAND. By G. V. Wilson, B.Sc., with contributions by John S. Flett, LL.D., F.R.S. 159 pp. 2 plates. 16 text figures - - - - - - - (1921) | 7 | 6 |
| VOL. XVIII. ROCK-SALT AND BRINE. By R. L. Sherlock, D.Sc. 123 pp. 2 plates. 16 text figures. Wrapper - - (1921) | 5 | 0 |
| VOL. XIX. LEAD AND ZINC ORES IN THE CARBONIFEROUS ROCKS OF NORTH WALES. By Bernard Smith, M.A. 162 pp. 3 plates. 25 text figures. Wrapper - - - (1921) | 5 | 6 |
| VOL. XX. LEAD AND ZINC: THE MINING DISTRICT OF NORTH CARDIGANSHIRE AND WEST MONTGOMERYSHIRE. By O. T. Jones, M.A., D.Sc., Professor of Geology and Mineralogy, Victoria University, Manchester. 207 pp. Coloured Geological Map. 27 plates. 4 text figures. Wrapper - - - (1922) | 7 | 0 |
| VOL. XXI. LEAD, SILVER-LEAD AND ZINC ORES OF CORNWALL, DEVON AND SOMERSET. By Henry Dewey. 72 pp. 4 plates. 14 text figures. Wrapper - - - - (1921) | 2 | 6 |
| VOL. XXII. LEAD AND ZINC ORES OF THE LAKE DISTRICT. By T. Eastwood, A.R.C.S. 56 pp. 1 plate. 4 text figures. Wrapper - - - - - - - (1921) | 2 | 0 |
| VOL. XXIII. LEAD AND ZINC ORES IN THE PRE-CARBONIFEROUS ROCKS OF WEST SHROPSHIRE AND NORTH WALES. PART I.—WEST SHROPSHIRE, by Bernard Smith, M.A. PART II.—NORTH WALES, by Henry Dewey and Bernard Smith, M.A. 95 pp. 13 text figures. Wrapper - - - (1922) | 3 | 0 |
| VOL. XXIV. CANNEL COALS, LIGNITE AND MINERAL OIL IN SCOTLAND. By W. Gibson, D.Sc., from contributions by J. S. Flett, F.R.S., E. M. Anderson, M.A., G. W. Lee, D.Sc., and M. Macgregor, M.A. 73 pp. 6 text figures - - (192 ) | — | |

*In course of Publication.*

VOL. XXV. LEAD AND ZINC ORES OF NORTHUMBERLAND AND ALSTON MOOR. By Stanley Smith, M.A., D.Sc., with contributions by R. G. Carruthers, F.R.S.E.

VOL. XXVI. LEAD AND ZINC ORES OF DURHAM, YORKSHIRE AND DERBYSHIRE, WITH NOTES ON THE ISLE OF MAN. By R. G. Carruthers, F.R.S.E., and Sir Aubrey Strahan, K.B.E., F.R.S.

*In Preparation.*

VOL. . COPPER ORES OF THE WEST OF ENGLAND. By Henry Dewey.

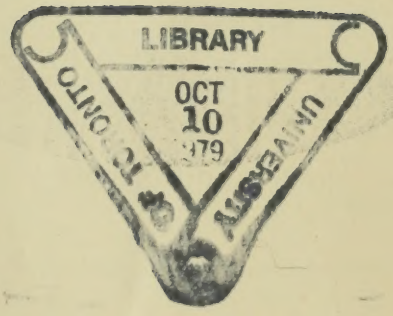
VOL. . COPPER ORES OF THE MIDLANDS, THE LAKE DISTRICT, AND NORTH WALES. By Henry Dewey and other contributors.

| | | s. | d. |
|---|---|---|---|
| Vol. . | Refractory Materials, Fireclays, Chemistry and Physical Tests. By F. R. Ennos, B.A., and other contributors. | | |

## MISCELLANEOUS ECONOMIC MEMOIRS.

| | | | |
|---|---|---|---|
| Thicknesses of Strata in the Counties of England and Wales, exclusive of Rocks older than the Permian. By A. Strahan, Sc.D., LL.D., F.R.S., T. V. Holmes, H. Dewey, C. H. Cunnington, B.Sc., W. C. Simmons, B.Sc., W. B. R. King, B.A., and D. A. Wray, B.Sc. 172 pp. 36 text figures. Wrapper | (1916) | 4 | 6 |
| The Oil-Shales of the Lothians. Part I. The Geology of the Oil-Shale Fields. By R. G. Carruthers, F.R.S.E., based on the work of H. M. Cadell and J. S. Grant Wilson. Part II. Methods of Working the Oil-Shales. By W. Caldwell. Part III. The Chemistry of the Oil Shales. By D. R. Steuart, F.I.C. 199 pp. 83 figures. Coloured Geological Map, table of comparative vertical sections and plate of fossils from oil-shale strata. Wrapper - | (1906; Edit. 2, 1912) | 2 | 6 |
| A Handbook to the Collection of Kaolin, China-Clay and China-Stone, in the Museum of Practical Geology, Jermyn Street, London, S.W. By J. Allen Howe, B.Sc., F.G.S., Curator, with an Appendix by Allan B. Dick. 271 pp. 9 plates. 55 text figures. Wrapper - - - - - | (1914) | 3 | 6 |
| Guide to the Collection of Gemstones in the Museum of Practical Geology. By W. F. P. McLintock, B.Sc. 92 pp. 43 text figures. Wrapper (*Out of print*). | (1912; Edit. 2, *in preparation*) | — | |
| The Ayrshire Bauxitic Clay. By G. V. Wilson, B.Sc. 28 pp. 2 plates. 2 text figures. Wrapper - - - | (1922) | 1 | 6 |
| Economic Geology of the Isle of Man, with Special Reference to the Metalliferous Mines. (Reprinted from the Geology of the Isle of Man). By G. W. Lamplugh. 185 pp. 2 illustrations. Wrapper - - - - | (1903) | 1 | 6 |
| The Geology of Falmouth and Truro and of the Mining District of Camborne and Redruth. (Explanation of Sheet 352.) By J. B. Hill, R.N., and D. A. MacAlister, A.R.S.M., F.G.S., with Petrological Notes by J. S. Flett, M.B., D.Sc. 335 pp. 24 plates. 65 text figures. Cloth - | (1906) | 7 | 6 |
| A Handbook to a Collection of the Minerals of the British Islands, mostly selected from the Ludlam Collection, in the Museum of Practical Geology, Jermyn Street, London, S.W. By F. W. Rudler, I.S.O., F.G.S., late Curator of the Museum. 241 pp. Wrapper - - - | (1905) | 1 | 0 |
| The Coals of South Wales, with Special Reference to the Origin and Distribution of Anthracite. By Aubrey Strahan, M.A., Sc.D., LL.D., F.R.S., and W. Pollard, M.A., D.Sc., F.I.C., assisted by E. G. Radley. 91 pp. 10 plates. Wrapper. | (1908; Edit. 2, 1915) | 2 | 0 |

Printed under the authority of His Majesty's Stationery Office
By Eyre and Spottiswoode, Ltd., East Harding Street, E.C. 4,
Printers to the King's most Excellent Majesty.


LIBRARY
OCT
10
UNIVERSITY OF TORONTO

SERIAL